U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1777

Training Critical Thinking Skills for Battle Command: ARI Workshop Proceedings

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July 2001

U.S. Army Research Institute
for the Behavioral and Social Sciences

A Directorate of the U.S. Total Army Personnel Command

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Research accomplished under contract
for the Department of the Army

Personnel Decisions Research Institutes

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) July 2001	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) December 2000 to July 2001
4. TITLE AND SUBTITLE Training Critical Thinking Skills for Battle Command: ARI Workshop Proceedings		5a. CONTRACT OR GRANT NUMBER DASW01-98-D-0049
		5b. PROGRAM ELEMENT NUMBER 622785
6. AUTHOR(S) Sharon L. Riedel (U.S. Army Research Institute), Ray A. Morath and P. Timothy McGonigle (Caliber Associates) (Editors)		5c. PROJECT NUMBER A790
		5d. TASK NUMBER 1141
		5e. WORK UNIT NUMBER C01
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600 Personnel Decisions Research Institutes 43 Maine Street SE Suite 405 Minneapolis MN 55414		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600		10. MONITOR ACRONYM ARI
		11. MONITOR REPORT NUMBER Research Report 1777

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

Contracting Officer's Representative, Sharon L. Riedel

14. ABSTRACT *(Maximum 200 words)*: The ARI Workshop, Training Critical Thinking Skills for Battle Command, was held on 5-6 December 2001 at Ft. Leavenworth. The purpose of the Workshop was to (1) provide an overview of current research in critical thinking and training critical thinking (CT), (2) provide a forum for identifying and discussing issues related to training CT in the Army; and (3) develop recommendations for training and for future directions for research and development in the area of CT training. Participants with a variety of expertise attended – military officers, instructors in CT and academic researchers in CT. The following papers were presented: *Critical Thinking in the 21st Century* by MG (Ret.) Lon Maggart; *Thinking Critically about Critical Thinking* by Diane Halpern; *A Framework for Critical Thinking Research and Training* by Susan Fischer; *A Three part theory of Critical Thinking: Dialogue, Mental Models and Reliability* by Marvin Cohen; *Critical Thinking in Teams* by Daniel Serfaty; and *A Simulation Tool for Critical Thinking Training* by Marvin Cohen. The Proceedings includes these papers, with the exception of the Serfaty paper. Workshop participants discussed a variety of issues related to training CT and their recommendations for training and future research are included in the Proceedings.

15. SUBJECT TERMS

Critical thinking, training, battle command, skills

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT Unclassified	17. ABSTRACT Unclassified	18. THIS PAGE Unclassified	Unclassified	135	Sharon Riedel (913) 684-9764

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5-6 December 2000
Fort Leavenworth, Kansas

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July 2001

Army Project Number
2O262785A790

Personnel Performance and Training Technology

FOREWORD

Critical thinking skills are essential to the effective performance of military leaders. Army XXI will be faced with a diversity of missions, faster pace, greater uncertainties, as well as changing equipment, digital capabilities, and organizational structures. All of these will place increasing demands on the planning and decision-making skills of Battle Commanders and their staff. Only through critical thinking can these leaders learn how to adjust to the novel and unpredictable situations faced on tomorrow's battlefields and to the various roles played by our Army. Despite the vital nature of critical thinking skills, our knowledge of its fundamental aspects is somewhat limited. Some fundamental issues on which there appears to be little consensus include: a definition of critical thinking; the extent to which it is possible to train leaders to think critically; how to most effectively measure critical thinking; and how to integrate critical thinking into current Army practices.

In an effort to address some of these issues, the U.S. Army Research Institute hosted the Army Workshop on Critical Thinking Skills for Battle Command at Fort Leavenworth, KS in December 2000. The purpose of this workshop was to bring together experts in critical thinking research and battle command to discuss both the latest research on critical thinking skills and how critical thinking skills relate to the Army's mission now and in the future.

This volume contains articles written by Workshop participants and recommendations for future work. The participants included highly regarded researchers from academia, industry and government who described the latest research in training critical thinking skills. Military participants in the Workshop provided evidence of the importance of critical thinking skills in battle command.

This effort was briefed to Dean of Academics, Army Command and General Staff College (CGSC), and beneficiaries of Workshop results included course developers and instructors of critical thinking in the CGSC Intermediate Level Education (ILE). The type of collaboration resulting from this workshop is an essential step in the development of new approaches and techniques to improve critical thinking skills in the Army.

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OVERVIEW

There is a growing interest in critical thinking skills in the Army training community as a way to equip officers to deal with the greater uncertainties and complexities of the future battle field, rapid technology advances and the explosion of instantly available communication and information. In support of this interest, the Army Research Institute's program includes developing methods for training critical thinking skills (CTS) for Battle Command. The ARI Workshop on Critical Thinking Skills for Battle Command, described in this Proceedings, provided CTS researchers and Army training developers with an overview of the latest research in CTS training and frameworks from which to consider methods for training and training evaluation. It also provided an opportunity for participants to explore together the challenges, problems, and solutions and the implications for developing and training CTS in Army Officers.

DESCRIPTION OF THE WORKSHOP

The Workshop, held 5-6 December 2000 at Fort Leavenworth, was conducted by the U.S. Army Research Institute with contract support from Caliber Associates. The Workshop was part of an ARI program of research dealing with identifying and training cognitive and critical thinking skills. It brought together participants with a variety of expertise – military officers, instructors in Critical Thinking Skills, and researchers. Because of this mix, the group was able to bring different perspectives to the issues that were discussed.

The objectives of the Workshop were to: provide an overview of current research in critical thinking (CT), adult learning, and CT training; provide a forum for identifying and discussing issues related to training CT in the Army; and develop recommendations for training CT in the Army and directions for future Research and Development.

The Workshop had two main sections. First, a series of presentations by academic researchers addressed what we know now about critical thinking and training critical thinking. Next, small groups discussed the implications of what we know for training and developing Critical Thinking Skills in Army officers. The groups also developed recommendations for training and future directions for Research and Development.

WORKSHOP PAPERS: WHAT DO WE KNOW ABOUT CRITICAL THINKING AND HOW TO TRAIN IT?

One of the purposes of the Workshop was to provide participants with a tutorial on what educators, psychologists, and philosophers know about training critical thinking. The papers deal with the major issues in critical thinking and training CTS. Critical thinking has engendered a

great deal of interest in the educational and training communities. A search of the Internet generated 219,601 citations (web pages) involving critical thinking. However, there is little consensus on what constitutes critical thinking and how it should be measured. Workshop papers give an overview of what we know about critical thinking and provide frameworks to integrate fragmented theories and research. The first presenter, MG (Ret) Maggart, sets the context as he discusses the need for critical thinking training in the Army. Diane Halpern then gives a general overview of training critical thinking and Susan Fischer describes a framework for conceptualizing critical thinking and its training that would be useful for research and designing training. Marvin Cohen provides a new theory of critical thinking that centers on dialog as a means of training CT. Daniel Serfaty describes what we know about training teams in critical thinking and Cohen ends with a description of work that is being done in developing a simulation of critical thinking for use in providing intelligent feedback to students.

In the first paper, *Critical Thinking in the 21st Century*, MG Maggart talks about the relationship between leadership and critical thinking and the need for critical thinking in the military. He cautions us not to reduce critical thinking to a process and describes the power of mentoring in shaping critical thinking. He challenges us with the problem of how to inculcate critical thinking into the Army culture given all of the existing demands on it. Critical thinking will not be inculcated into the Army system unless there is a dramatic shift in the existing Army culture. Not only must the Army become tolerant of critical thinkers, but value them and reward them.

Next Diane Halpern applies cognitive science to the teaching of critical thinking in her paper *Thinking Critically about Critical Thinking* and presents persuasive arguments for why we should train critical thinking. She points out that critical thinking training is predicated on two basic assumptions: (1) there are identifiable critical thinking skills which students can be taught and (2) that if applied will improve thinking. Halpern points out that research shows that students can be taught to become better thinkers and that critical thinking skills transfer to novel situations when we teach for transfer. She proposes a model for critical thinking instruction and a taxonomy for organizing college-level critical thinking skills.

Theoreticians and researchers have been interested in critical thinking for over fifty years. Despite this interest, the area is very fragmented and there is not a dominant theory of critical thinking. Researchers cannot even agree on a definition of critical thinking. The next paper, *A Framework for Critical Thinking Research and Training* by Susan Fischer, presents a framework for critical thinking that is based on an extensive review of the educational, philosophical, and psychological literature. The purpose of the framework is to integrate past research and theories to develop a model that would be useful for guiding the research and training of critical thinking. This model provides a starting point for the Workshop discussions on critical thinking. Fischer first presents an overview of the work that has been done in academia, the educational arena, and industry. Then, she integrates and combines others' theories to propose a model of critical

thinking that provides a structure for the aspects of critical thinking that should be considered when designing and conducting training in critical thinking. The results of the application of this model to critical thinking in the domain of Army command and control are described. She also provides a list of CTS that have appeared in the literature. The model has implications for training critical thinking and these are discussed. During the Workshop participants suggested a number of changes to the model and these are discussed.

In *A Three-part Theory of Critical thinking: Dialogue, Mental Models, and Reliability,* Marvin Cohen makes the case that critical thinking is an important Army battlefield skill, and that its importance is likely to increase. But it is necessary to consider some potential problems that may arise if concepts developed in academic contexts are transferred to the battlefield. He presents and explains a theory of critical thinking, and shows how it addresses some of the problems inherent in Army applications. According to this theory, critical thinking skill is exemplified by *asking questions about alternative possibilities in order to achieve some objective.* Asking and answering questions is a skill of *dialogue.* Alternative possibilities are represented by *mental models.* A process of questioning mental models is adopted because of its *reliability* for achieving the purposes of the participants within the available time. This paper also addresses questions such as: Is CT consistent with tactical battlefield constraints? Is CT consistent with other battlefield skills: Is CT appropriate for the military organizational structure? Will CT fit into Army training?

In his paper on *Critical Thinking in Teams,* Daniel Serfaty reviews the state of knowledge on team performance and delineates those aspects of critical thinking and adaptation strategies which are unique to high-performing teams. The paper discusses the relationship between the constructs of shared mental models, implicit coordination, and teamwork-related critical thinking processes. Hypotheses are proposed on the factors that could enhance critical thinking in teams, leading to the timely and correct decisions to communicate information, coordinate actions, or even restructure the organization. Potential team training strategies that focus on self-observation and adaptation training are suggested. Serfaty concludes that while team performance research has seen a renewed interest in the last few years, very little attention has been paid to the specific critical thinking processes that occur in command teams.

The final paper, *A Simulation Tool for Critical Thinking Training, by* Marvin S. Cohen, Bryan B. Thompson, & Lokendra Shastri, describes a simulation technology that combines (1) the ability to perform rapid recognitional inferences and planning within a large (expert) belief network, (2) human limitations on computational resources and attention, and (3) critical thinking skill. This tool could form the basis for the development of an adaptive training system, which presents realistic military decision making problems, tracks trainees' responses, and provides appropriate feedback and coaching to improve both recognitional and critical thinking skills.

DISCUSSION RESULTS: CRITICAL ISSUES AND RECOMMENDATIONS

In the second part of the Workshop, participants broke into small groups to discuss critical issues in CT training for Army officers and in CT research. Following is a summary of the recommendations produced by those discussions.

RECOMMENDATIONS FOR IMPROVING CT TRAINING IN THE ARMY

- Foster an Army culture that values CT
- Train interpersonal skills for the application of CT
- Instructors should model use of CTS in every course
- Design digital capabilities to aid and facilitate CT and use these capabilities when training CT
- Include CT training in every course that's taught in the Army
- Train for transfer of training
- Explicitly train the process of critical thinking; instructors should model CT in all of the Army officer courses
- Capitalize on what works well now.

CRITICAL ISSUES FOR FUTURE RESEARCH AND DEVELOPMENT

- Development of valid evaluation methods and measures of CT
- Team training of critical thinking
- Individual predispositions to CT. What conditions elicit CT? What conditions stop CT?
- Simulations to explore "what if" thinking and provide intelligent feedback.

CRITICAL THINKING IN THE 21ST CENTURY

MG (RET) LON E. MAGGART

Thank you very much for allowing me the opportunity to address this very distinguished group. I am pleased to be here today because I have studied and thought about critical thinking for many years and believe it is not only an important topic, but also one that is essential for the success of the Army in the future. I am also very pleased that ARI has seen fit to address this important subject today…it couldn't have been better timed given the challenges facing the Army today.

Before I start, let me say that the short talk just presented by Ed Johnson was most eloquent. It is almost as if we colluded on this presentation. He stated more clearly than I will the significance of understanding and practicing critical thinking. Let me also say, Ed, that every Army officer alive today has read Once An Eagle. Each can categorize him or herself as either Sam Damon or Courtney Massengale. More importantly, each can categorize their fellow officers likewise…and do.

I think the short answer to your question about the difference between these two characters is that Sam Damon took care of people. He worked his way to the top with care and concern for people. Massengale got to the top on the backs of the subordinates and peers whom he stomped into the ground as he ascended. The difference is that Sam Damon made a positive difference in the lives of all those with whom he came into contact. Massengale may have been respected for his guile, but he was never admired for his character. The lesson for us all from this story is this: take care of people and make their experience in the organization positive. Leadership success is transforming people to be better than they were, not using them for personal gain.

Well, on with the lecture. I borrowed the following passage from Dr. Seuss…by the way, it is one that General Gordon Sullivan used when he was trying to get the Army to think about digital operations—captures the essence of my message today.

CRITICAL THINKING

Think left and think right
and think low and think high
Oh, the thinks you can think up
if you only try!

Dr. Seuss

FIGURE 1

To be a critical thinker, one must first learn how to think, then practice it without imposing limitations or constraints. I am not so sure that Dr. Seuss isn't worth reading as adults for the mental stimulation it provides and I started to bring a number of copies with me to hand out today for that reason. I would like to take just a few minutes to put critical thinking in the Army into some historical perspective.

While Dr. Kathy Quinkert and others were conducting research on digital operations at Fort Knox in the late 1980's, a general understanding of the potential of operating digitally did not begin until the early 1990's when the Army began to critically analyze the Gulf War and the possibilities for future war that were enabled with the new M1A2 Abrams tank. The inherent capabilities of this new tank provided a glimpse into the enormous improvement that was possible for the entire combined arms team because every member of the team could simultaneously share written and graphical information on every tactical operation whether deliberate or hasty. The possibilities for how the Army could fight more effectively and efficiently were verified during the first digital experiment conducted at the NTC in the summer of 1994. This experiment changed forever, at least intellectually, notions about how the Army could fight and set the stage for what only can be described as a revolution in tactical thought...at least for those capable of critical thought.

It was precisely in the months following this experiment that new and exciting skills—critical thinking skills—were identified that leaders needed to successfully execute high tempo digital operations. Most of this early work was done at Fort Knox because the M1A2 tank was the genesis of digital operations. But more importantly, Fort Knox was the agent for change in the Army's digitization effort in large part because the leadership at Fort Knox had the vision to see the possibilities and perhaps most importantly, understood the power in using simulations to work through complex problems.

Interestingly, those working most closely with the conversion to digital operations discovered that these new skills also posed several unique training problems. First, coursework existed for virtually none of the new skills identified. Secondly, even though there was a direct correlation between these new skills and using the digital equipment for a more significant battlefield payoff, the Army had no real strategy, or mechanism to train soldiers on how to use digital equipment differently from existing conventions to achieve better battlefield effects. The Army knew how to train soldiers to operate the equipment, that is turn it on and off, access menus and so on...it was expert on such training. But the Army did not know how to train soldiers to use the equipment to conduct tactical operations in ways that demonstrated the significantly improved battlefield results the equipment was capable of producing. The major impediment to progress then, and to a large extent now, was an attitude that digital tasks and skills are the same. They are not. The biggest hurdle we continue to confront is getting people to understand that one can fight differently using digital equipment.

For example, the new digital equipment made it possible to mass fires and not forces on the battlefield, but there was no conceptual tactical framework within which to do this and certainly no methodology to teach it. Nor was there any concept on how to make existing command and staff actions more efficient. In fact, some of the great minds of the time simply wanted to automate the existing five-paragraph field order as a way to address the problem. So the emphasis was put on what the Army knew how to do best—teaching soldiers how to work the machines. Unfortunately, little or no thought was expended on how to make the machines give soldiers a decided advantage on the battlefield. The first point I want to make here is that whatever comes from this conference in the way of developing strategies for critical thinking, please be mindful that the payoff is in the way soldiers and leaders can convert brainpower into combat power.

The second point I want to make is that the Army is basically a process driven organization, more interested in standardization of thought than in divergent thought. Critical thinking clearly requires divergent thought, so as you discuss critical thinking over the next two days, please try to resist the urge to develop another military decision making process or a command and staff action process. If you do so, it will be doomed by the same limitations and restrictions to productive thought from which these and other Army processes currently suffer.

To that point, Figure 2 represents my notion of critical thinking. It is a process only in that it involves interaction between the subject areas shown on the periphery and probably a few we haven't thought of, and a product of some kind. From my perspective, critical thinking is far too complex to reduce to a simple algorithm anyway. But again, because the Army is process oriented, the urge to do so will be overwhelming. This is a caution to all of you! If you describe critical thinking as an algorithm, that is what the Army will teach and students will learn...but unfortunately they will not learn how to think critically!

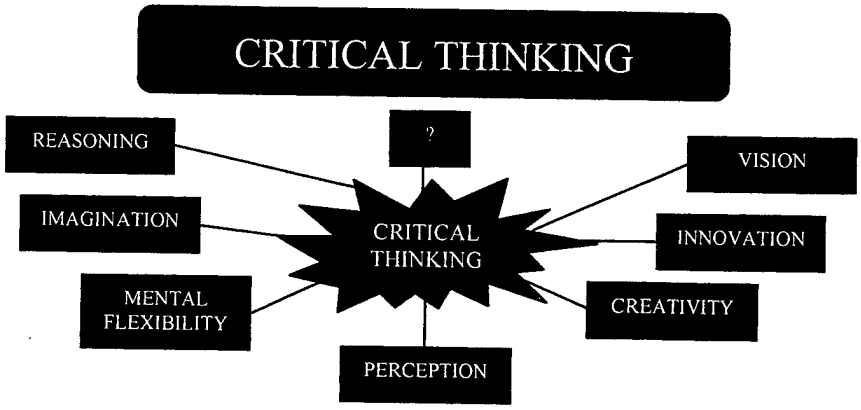


FIGURE 2

Once the world and subsequently the Army moved into the Information Age, life became more rather than less complex in most respects.

Leaders now must deal with an entirely new set of intellectual, cultural and equipment challenges that were not present just six years ago. These challenges plus the advent of digital information systems that allow communications at rates and to places never before possible and way more data than a normal human can deal with, all require substantial changes in the skills required of leaders as well. Traditional leadership techniques and practices simply will not suffice in the months and years to come. Leaders must therefore be able to think on their feet, make rapid and accurate decisions, take the initiative, be more aware of their capabilities and adapt instantly to rapidly changing even chaotic situations using divergent thinking to process enormous amounts of information to reach an acceptable solution that will deal effectively with the circumstances.

(One of my aforementioned colleagues commented on the thought this way: "They have to understand what the technology enables them to do and then get on with leading. Part of the problem is that many people want to be the operators of the equipment rather than users of the capability. The Army needs technically capable people, but not in the combined arms leadership role. There also needs to be an understanding that this technology will empower subordinates to think and act in ways never before possible. But to achieve that which is possible, the Army can't continue to treat NCOs and Enlisted personnel as they have in the past or it will lose the backbone.")

Figure 3 compares traditional leadership skills with those required for success in the near future. I have highlighted the skills that I believe require critical thinking for success.

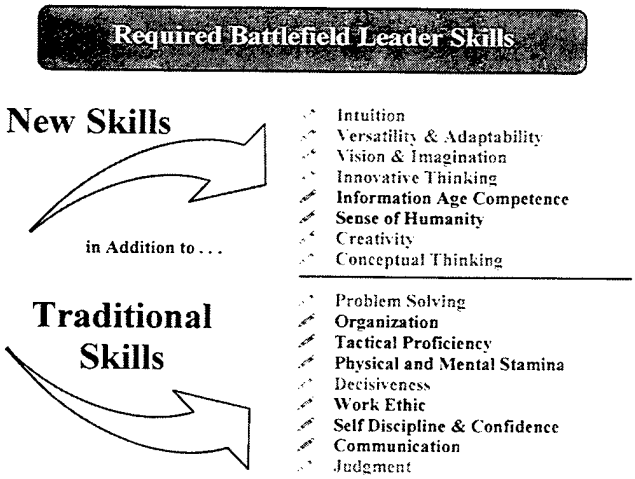


FIGURE 3

Meanwhile, Figure 4 illustrates several leadership challenges for this century and the skills necessary to cope with them. I think it is fair to say that virtually none of these skills are currently in the curriculum of any Army school.

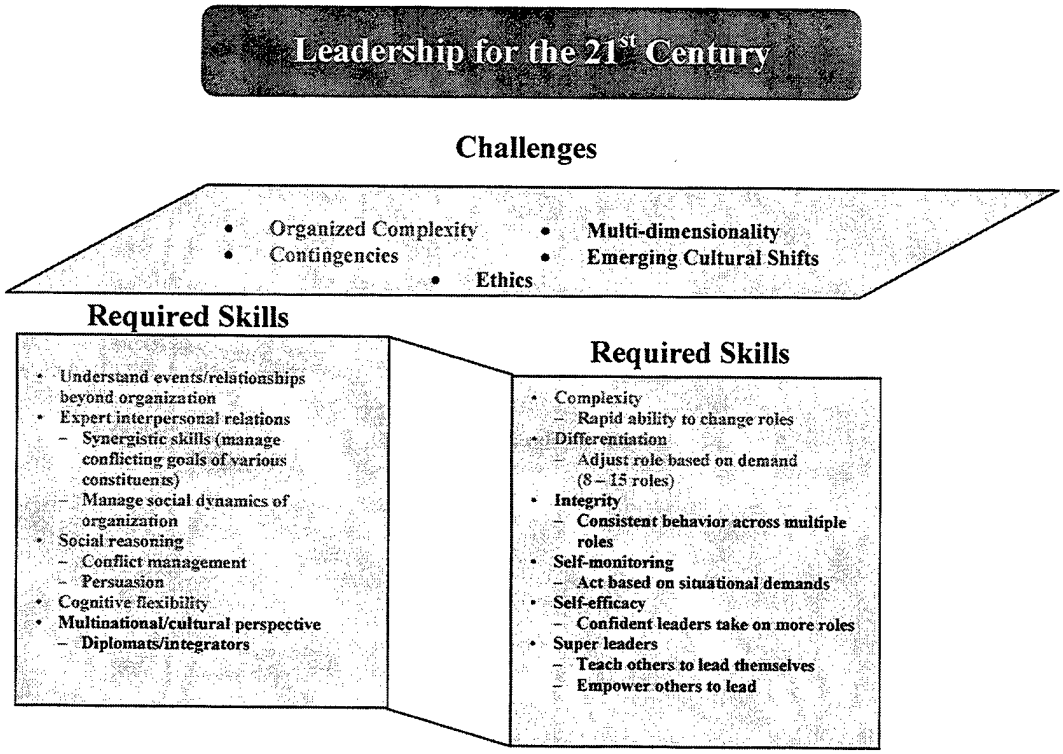
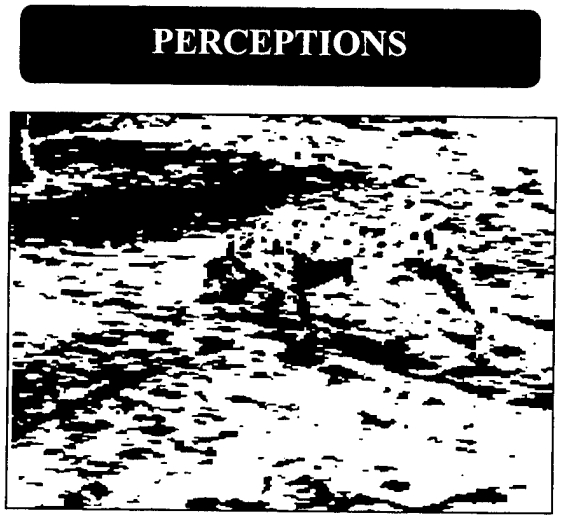


FIGURE 4

The skills highlighted are those I believe require critical thinking to be successful. Please note the frequency with which you see terms like adaptability, flexibility and the ability to adjust to changing circumstances. Clearly we will have to start teaching leaders these skills very early in their careers if we hope to develop senior leaders who are mentally flexible. The entire area of leadership is in flux now in part because of the cultural, interpersonal and organizational changes necessary to cope with the enormous potential of information age technology.

I think that every great leader I have known or read about was able to coalesce disparate, complex thoughts, ideas and concepts into a single expression that everyone could understand. Great leaders are able to see things that others cannot. All of them not only see the big picture; they have the special ability to explain it so others can see it as well. And lastly, all great leaders believe that the mind is the most powerful weapon in their arsenal. All great leaders spend more time thinking than talking...despite what you normally see or hear around the Army.

How many of you can see the picture in the middle of this sea of black dots (Figure 5)? There is a hunting dog there. Do you all see it?



A random dot pattern?

FIGURE 5

The point I want to make is, like it or not, your brain processes what it sees in ways that may mislead your thought processes.

In a manner of speaking, you may be critically thinking about the wrong thing. Your brain will focus on the big picture, then try to improve the organization of the material it sees. My colleague Dr. Robert Hubal would suggest the word is "impose" not "improve," but in either case, your brain tries to make sense of what it sees. Context is important in helping the brain interpret what it sees so you can be misled easily if you don't understand the context. The lesson here is to make sure that you have the correct input before you grind through some critical thinking process. You must be specific about your focus. Sometimes you will need to see the big picture, sometimes the details. The trick (necessary skill) is to know when to focus on which.

We have been talking sometime now about the relationship between leadership and critical thinking and the requirement for critical thinking skills. The real question is how do we inculcate critical thinking into Army today given all the existing demands on it. Figure 6 represents my concept of how to accomplish this. This diagram is roughly equivalent to the current three-legged system the Army uses to model training: individual study, schoolhouse instruction and training conducted in units. It is also a reflection of my own experience over 30 years. I attribute whatever critical thinking skills I possess to exposure to these three factors. I think that a combination of literature, exposure to powerful minds and the ability to use simulations for creative thinking are the key tenets to successfully integrating critical thinking into the Army.

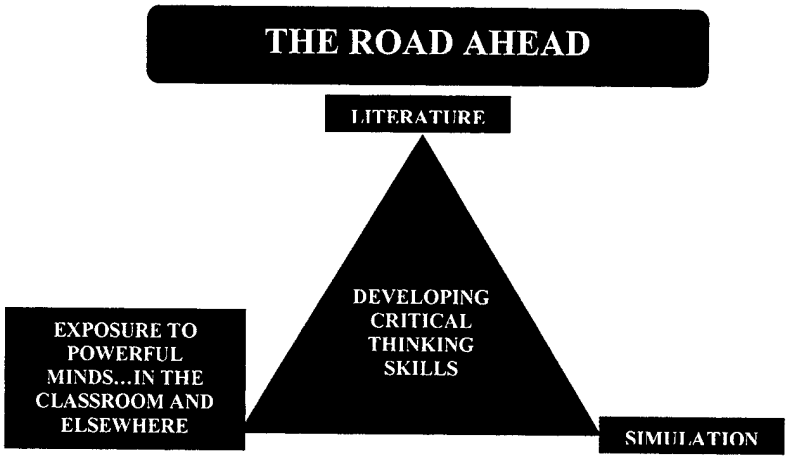


FIGURE 6

At the pinnacle of the triangle is literature. I am not talking here about providing to students a comprehensive bibliography or a suggested reading list. Rather I am talking about giving to some reputable institution like ARI the requirement to review all pertinent literature and develop a compendium of information that best captures the essence of critical thinking. I should make it clear here that I am not talking about collecting articles and papers into a book. What I am talking about is collecting sentences and paragraphs from existing works that precisely get at the essence of critical thinking. If one collected the short historical vignettes the Army sometimes uses in its field manuals into a single volume on tactics, this is close to the idea I have in mind. I believe that this compendium should be revised annually and available to everyone on the Internet. In addition, I think the old Excelnet, or something like it, should be revived to provide an open forum across the Army for people to discuss critical thinking.

Do any of you remember the Excelnet? I didn't think so. The Excelnet was established in the early 1980's by a friend of mine named Mike Rodier, now deceased, as a mechanism for discussing across the Army, a variety of subjects generally related to tactical doctrine. For example, there was a special section just for battalion commanders who were on rotation to go to the NTC. I found this, as did many of my peers, to be a most useful tool as there were interesting lessons learned, ideas, tactics and techniques and procedures discussed on this net. Everyone who participated was free to provide whatever input seemed appropriate. It was the forerunner to current chat rooms. Occasionally Mike would ask a participant to expand a particular point that he or she had discussed on the net into an article. Mike then collected and published these articles in a volume that was distributed around the Army. Unfortunately, many young leaders used the Excelnet to vent on the Army's senior leadership much as they do on the Internet today and it was disbanded after a few years. I believe that we should use a similar process to discuss critical thinking, publish selected works and make them available across the Army.

I believe that direct contact with unique individuals of powerful intellect, creative minds and interesting life experiences is essential in expanding ones own power of critical thinking. It

is like the Dr. Seuss example earlier; you just don't know what you don't know until someone explains something new to you. My exposure to great minds like Jack Woodmansee, Gordon Sullivan, Dee Hock—who thought up and put into being the VISA credit card company—Peter Senge, Margaret Wheatley, Mike Malone and others certainly expanded my ability to think. And I might add here that powerful minds aren't the sole province of older, established intellectuals. Some of the most powerful influences on my intellect came from people younger than I. I learned some of the most important things imaginable from the likes of Major Art DeGroat and Colonel Greg Fontenot sitting right here in this room. Mike Shaler remains a trusted agent against whom I can bounce ideas. Colonel Jeanette James, an Army nurse, taught me things I had never even thought about before and along the way a pretty healthy way to think about gender issues. Dr. Kathy Quinkert has been a valued colleague advising me on a range of topics from training to human interaction. To this day I send almost every significant thing I write to each of these people for their opinion. If one isn't concerned about another's age, rank or gender, it is truly amazing what one can learn!

Now clearly the Army can't afford to send a parade of famous, high dollar personalities around to every schoolhouse and post. But the Army certainly can afford to hire some of these folks to make videotapes, write papers or tape lectures that can be sent around in this fashion. The Army can also afford to link special meetings and conferences with thirty minutes or an hour of discourse by some noted intellectual. And there are plenty of intellectuals who can entertain as they transmit information.

I remain a tremendous fan of mentoring. Not the designated kind of mentoring the Army uses, but the kind that forms from mutual interest in a subject or perhaps because of an emotional bond between the mentor and mentee. In fact I would venture that it is possible to pass more information in a shorter period of time using mentoring than in any other single method of teaching. If you think of the ability of a mentor to take all the time necessary to explain complex thoughts in depth, to give personal examples and to answer questions virtually any time, day or night, it is easy to understand the power of mentoring. As an aside, there probably is no question off limits between a mentor and a mentee, so sensitive subjects can be discussed that would otherwise be impossible.

In any event, the Army must take special pains to ensure exposure to a wide and diverse range of powerful minds. This includes individuals who espouse views contrary to those valued by the Army or even the Federal Government for that matter.

My last point on this subject is a plea for the Army to relax its too stringent restrictions on the personal use of government computers and access to the Internet. My view has always been that the Army needed to promote divergent thought amongst it soldiers and leaders not restrict it. What better way than to use email for interaction between people? And it is clear to me that the enormous benefit gained from people internetting thoughts, ideas and experiences far exceeds any problem that results from "abusing" the system. If one is found to be frequenting

porn sites or using the system to run a personal business, the organization has a different problem than "misuse" of computers.

The final leg of my triangle concerns the use of simulations as a tool for the intellectually curious to consider advanced thoughts in a dynamic environment against a range of possible constructs.

For this to be a reasonable course of action, the Army must invest in research and development into the best kind of simulation and/or model for this purpose. It may well be possible to adapt an existing simulation like Janus, but in any event, some energy needs to be expended in this area. For this notion to work simulations chosen for this purpose must be accessible to Army and DOD civilians on every large post in the Army who want to use it. There must be minimal restrictions on what the simulation is used to investigate and the results of these simulations must be made available across the Army through some mechanism like Excelnet. And since we are dealing with ideas and thinking, the process is not so important as the product. In other words, it will not be necessary to produce statistically analyzed data for the product of these simulations to be significant or to be disseminated across the Army. Wild speculation will be acceptable as a by-product of these simulations. The bottom line is that simulations that permit "out of the box" thinking and experimentation must be accessible to all who have an interest in engaging in this kind of activity if we are going to push the frontier on critical thinking.

To illustrate this point, let me give you an example of something we did at Fort Knox five years ago. We assembled a group of very smart majors and captains who planned and executed an offensive operation with a fully digitized mounted brigade against a modernized opposing force defending a piece of terrain. We postulated the capability of such a force and then modified the variables in the Combat Developments Janus simulation to accommodate these parameters.

I brought in all of our foreign liaison officers to serve as the command group for the opposing force. We then executed an operation in which we infiltrated the entire brigade through the defensive lines of the opposing force without being detected. We destroyed the bulk of the opposing force by maneuver, massing the effects of fires without massing forces except when absolutely necessary. We also suffered few casualties and reached a decision favorable to the friendly force considerably more rapidly than would have been possible with a convention force of similar size conducting an operation appropriate for such an organization.

This exercise permitted us to conduct an operation at a time in the future against an opposing force that did not exist with a friendly force organized in a way that did not exist, equipped with digital systems that did not exist and using tactics that did not exist at the time we conducted the experiment.

We derived a number of compelling insights into how battles could be fought if a unit was equipped in a very specific way. This excursion allowed us to think critically about future

operations in ways that never would have been possible by conjuring in classroom. And we did so in the course of an afternoon, not after weeks of intellectual exploration. Curiously, it occurred to me that this was precisely the way we should be establishing our acquisition requirements documents and evaluating operations and organization concepts as well. It was also one of my earliest insights to the power of using simulations to promote critical thinking.

Let me now illustrate a practical implementation of critical thinking. I sent the next series of slides to General Sullivan when he was the CSA as a way to help him think through the complex problem of integrating disparate Army processes in a different way. I sent him these slides for two reasons. First to define the problem that I thought he had in trying to run an Army who's major operating systems at best were uncoordinated and at worst dysfunctional. Secondly, I wanted to illustrate how critically thinking through the problem could offer some tangible solutions.

I tried to define the problem by illustrating how the major Army systems currently worked. Notwithstanding the "How the Army Runs" (HOWTAR) chart made famous by General Max Thurman, in reality all of the major Army systems were stovepipes. Note than there was no linkage between any of them. Anomalies had to be managed manually by the DA Staff. This fact created massive inefficiencies in the system that impacted greatly on the operating forces in the field. As a case in point, I tried unsuccessfully for years as the Deputy Commanding General and later as the Commandant of the Armor School to convince TRADOC that there was no actual correlation between dollars, people and the Program of Instruction (POI) even though my budget and manpower were managed as if there was.

I think the Army recognized there were inefficiencies in the system and at least on a global scale, tried to fix them as illustrated in Figure 7. Note that the fixes were merely band-aids and none, save for Louisiana Maneuvers and the Joint Venture efforts, even made the attempt to link all of the DOTLMS. The problem with band-aid solutions is that they are temporary fixes, they create a new set of problems that exist outside the established processes and they continue to drain resources long past when they are useful.

THE ARMY "FIX"

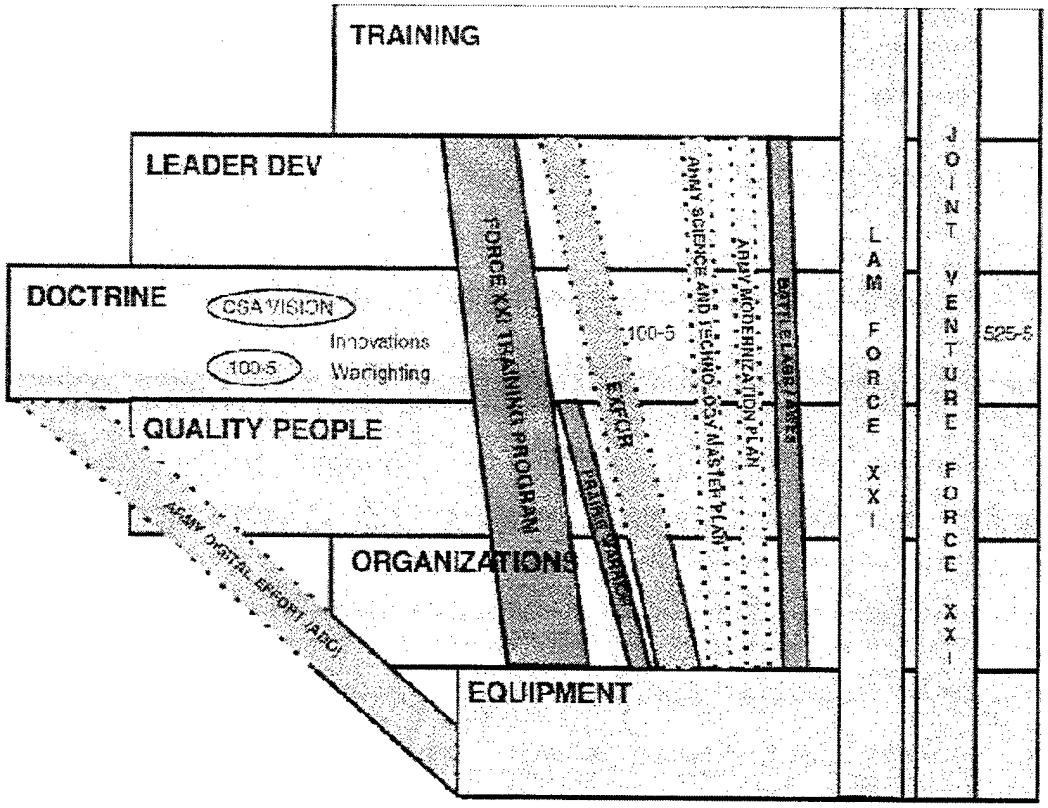


FIGURE 7

I suggested a solution that used existing processes to integrate the stovepipes in a way that resulted in a rope rather than a series of unrelated pieces of string. Note that critical thinking is the oil that lubricates the process (Figure 8).

THE REAL SOLUTION

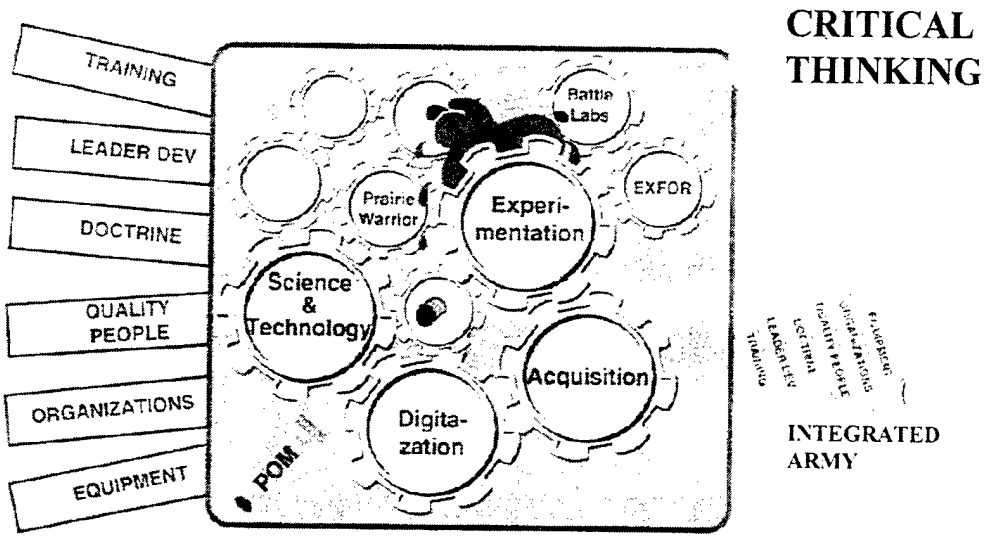


FIGURE 8

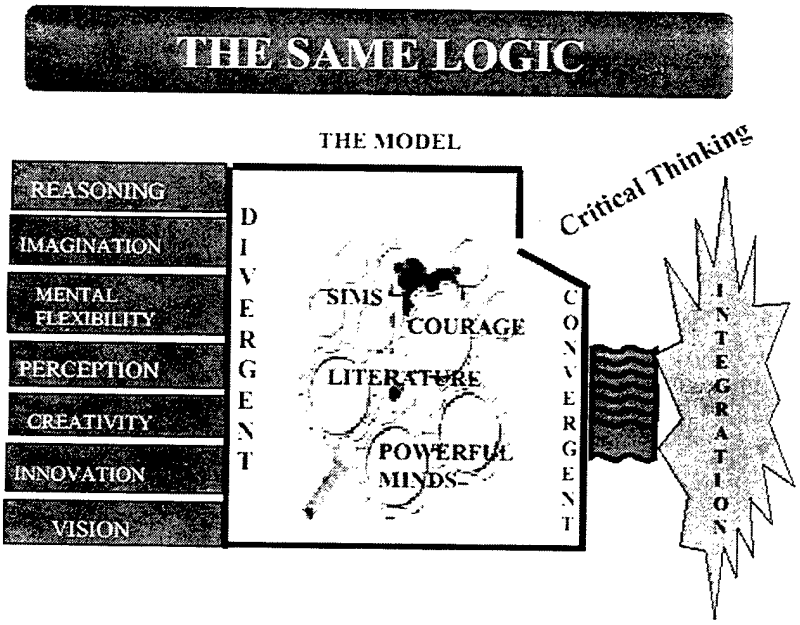


FIGURE 9

Our job at this conference is to figure out how to weave the various components of critical thinking into a process that provides a mechanism for the Army to integrate critical thinking into its day-to-day activities in a positive, non-disruptive way as illustrated by Figure 9.

There is one key point to this process that might not be immediately apparent from the figure. Note that on the left side I have the word "divergent" and on the right side the word "convergent." The concept I am trying to convey is that the process of critical thinking employs a number of different divergent thinking skills, that is, creativity, innovation and so on, to permit the widest range of thoughts to be considered as the basis for developing an informed decision. The process must then have some mechanism to converge this collection of thoughts into a decision or conclusion.

About two years ago, I gave a lecture at Fort Benning for Scott Graham on Situational Awareness. In conjunction with the lecture, Dr. Hubal and I prepared a paper in which we developed a situational awareness model partially as a way to describe the function of intuition in military decision-making. As I thought about how to explain my view on critical thinking for this group, it occurred to me that the situational awareness model was in fact also descriptive of this process as well. In fact, while the model was designed as specific to situational awareness, much of it may well be generally applicable to critical thinking processes.

If you will refer to Figure 10, I think you quickly will see how we adapted the model for critical thinking. Note that automatic and conscious decision processes are central to the Critical Thinking Model. Both of these processes involve what we describe as native skills such as imagination, visualization, innovation and so on. We believe it is possible to learn and/or refine these skills, although we clearly provide for innate talent by identifying the bulk of these skills under a category entitled "Native Skills."

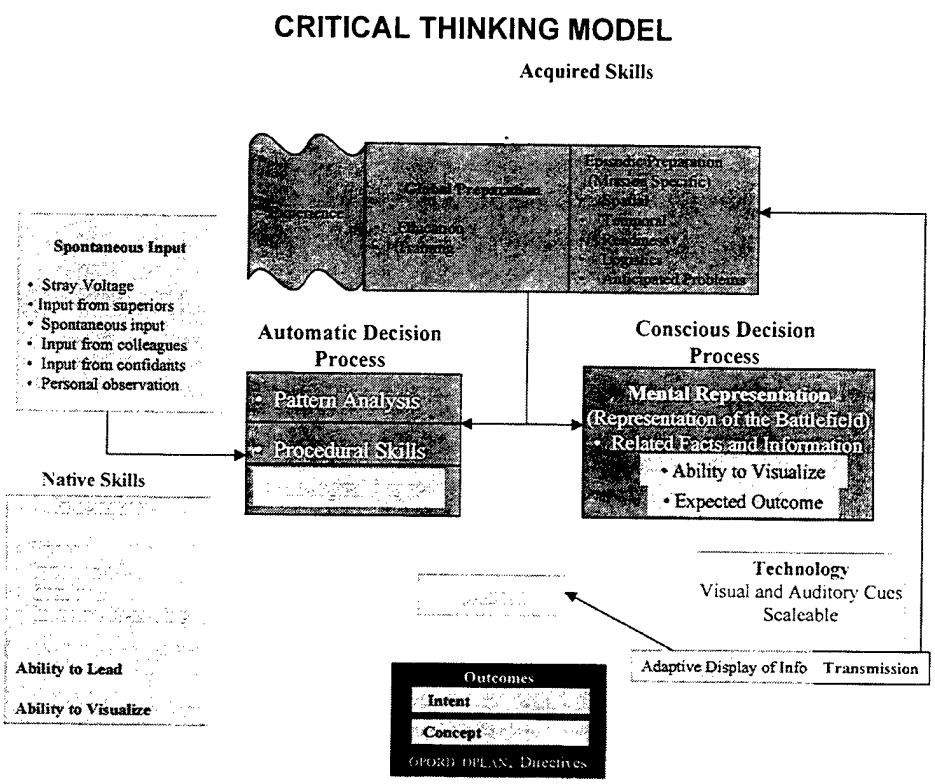


FIGURE 10

We believe that the conscious decision process involves the formulation of mental representations that are achieved using visualization and known facts about the battlefield. We used the expression "analogical engine" to refer to the automatic or subconscious decision processes that use one or several native skills in concert with established well-learned patterns or procedures. We believe that battlefield decisions involve a combination of both conscious and automatic processes. Both processes are fueled, sometimes instantly, sometimes as a product of deliberate reasoning over an expanded period of time, by external inputs. These inputs take the form of perceptual and motor skills acquired through experience and education and episodic or mission specific information and data acquired spontaneously while the event is underway from a variety of sources. Both automatic and conscious decision processes can be enhanced by the way technology is used to organize, evaluate, monitor and portray information.

Curiously, the Army appears to have a better understanding of critical thinking than it does about the kind of environment that is necessary to develop it. Figure 11 represents an unscientific sample of views around the Army on the subject of critical thinking.

Some Thoughts on Critical Thinking From the Field

"The down side to critical thinking in a military culture that does not embrace and value it is a learned sense of frustration over the lack of interest to do something with an unconventional perspective or novel proposal or idea. Most of our greatest cynical officers are frustrated critical thinkers who have given up that the institution will ever listen!"

"The Army has more critical thinkers than it benefits from because senior officers do not encourage, appreciate or reward their different ideas."

"Critical thinkers unconstrain themselves from the situation to 'see' possible solutions—then go back and modify conditions to make their system WORK!"

"Critical thinkers are more outcome/results oriented than non-critical thinkers who are content with the idea that if they follow established procedures, then the desired effect will result."

FIGURE 11

It is clear from these comments that there is a reasonable understanding of critical thinking in the field and more importantly, there are people who are willing to use critical thinking skills...if only they were permitted to do so. It is equally clear that the current Army culture neither encourages nor is tolerant of those who think outside the box. The point is that even if we were to design a functional program exactly as I described earlier, critical thinking will not become inculcated into the system until there is a dramatic shift in the existing Army culture. As a minimum this shift must include tolerance for divergent thought, but hopefully, it will swing more toward the positive end where those capable of such thought become valued members of the Army.

There is more to the problem of expanding critical thinking in the Army than developing a curriculum and creating an environment that encourages or at least is tolerant of it. The Army must underwrite tolerance for intellectual diversity and be flexible in accepting alternative solutions. Most importantly, the Army must underwrite the decision by men and women of character to take a stand against established but dysfunctional or illogical norms. Senior leaders, in particular, need to understand that there are valid perspectives, viewpoints and opinions that differ from their own that have equal or greater merit.

Soldiers and leaders need to understand that it is hard to be a critical thinker if the most important thing is another promotion and the ideal assignment. Those who worry about making career-ending mistakes will never be satisfactory critical thinkers.

So, in conclusion, ladies and gentlemen, (Figure 12) describing the way ahead is relatively simple. We must attack each of these three areas simultaneously. First, we need to change the Army culture so that both critical thinking and critical thinkers become acceptable and important. This can only happen if the Army's senior leadership creates the proper environment by adjusting the various selection processes to recognize, promote and school individuals with these skills; by assignments that reward critical thinking skills and lastly; by modifying the officer efficiency report so that individuals who possess critical thinking skills can be identified, managed and more importantly, rewarded. Secondly, we must decide on a theoretical construct or model with which everyone can live that describes critical thinking. You can use the one Rob Hubal and I developed, expand the one Susan Fischer offered or create something entirely new. In any case, the model selected then becomes the basis for developing strategies for thinking about, teaching and applying critical thinking skills. Lastly, we must define some process for inculcating critical thinking into our school systems, units and of course our leaders and soldiers in a fashion that does not disrupt an already overtaxed system.

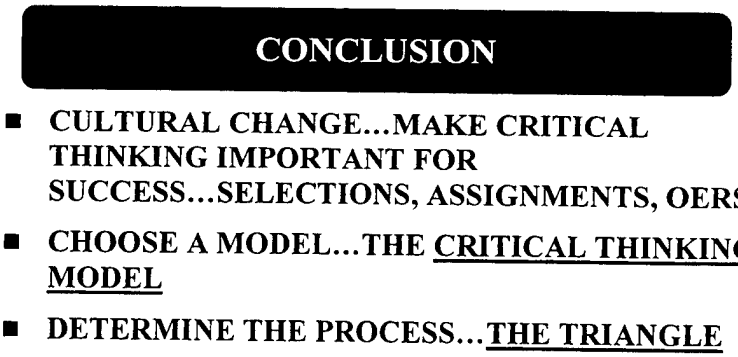
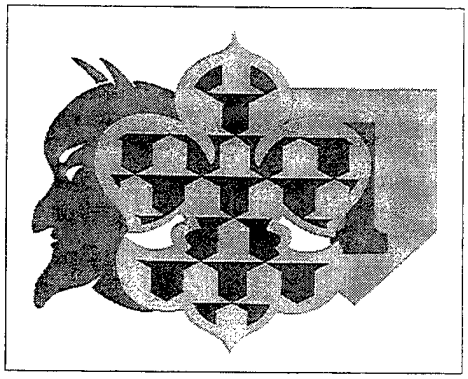


FIGURE 12

I use Figure 13 in part because it best describes the mindset that will be necessary to make critical thinking a reality in the Army. NO MISSION TOO DIFFICULT, NO SACRIFICE TOO GREAT, DUTY FIRST. Thank again for having me today. It was a great pleasure and honor for me.

NO MISSION TOO DIFFICULT
NO SACRIFICE TOO GREAT



DUTY FIRST!

FIGURE 13

THINKING CRITICALLY ABOUT CRITICAL THINKING: LESSONS FROM COGNITIVE PSYCHOLOGY

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Let me give you some scary facts about the American public. First, a large percentage start everyday by reading their horoscope and believe that it is so often correct that it's as though it was written especially for them; they phone their personal psychic, at a cost that many cannot afford, for advice on matters that range from how to invest their money to whether or not a loved one should be disconnected from life support systems; they spend huge sums of money on a variety of remedies for which there is no evidence that they work or are even safe to take—sometimes with disastrous results. In a survey of college students, more than 99 percent expressed belief in at least one of the following: channeling, clairvoyance, precognition, telepathy, psychic surgery, psychic healing, healing crystals, psychokinesis, astral travel, levitation, the Bermuda triangle mystery, unidentified flying objects (UFOs), plant consciousness, auras, and ghosts (Messer & Griggs, 1989).

Of course, there are a variety of the alien abductions, the unconscionable charlatans who make money by helping grieving people keep in touch with their deceased loved ones, and many more. If you're not worried yet, consider that political candidates and public policies are marketed to the general public with the same techniques that are used to persuade us to buy the "toothpaste with sex appeal." Let's add to this list the so-called "historical societies" that deny or minimize the atrocities of the Holocaust and related groups that explain that most slaves in the United States enjoyed their protected status. Arguments in support of the second statement sometimes take the form that slaves were valuable property, and few would be willing to mistreat or damage their own valuable property. Therefore, most slaves must have been treated well. There is an embedded and seductive logic, albeit a flawed one, that is used to explain a wide range of beliefs. Of course, there is also rationalization—the hunting for reasons, even weak ones, to support a preconceived conclusion. I probably should also mention the flat earth society, a society based on the belief that, you guessed it, the earth is flat.

Given all of these examples, it is not surprising that many colleges in the United States and other places throughout the world now require all students to take a course in "critical thinking" as part of their general education program. Although there has been considerable disagreement over who should teach such courses, whether they should be "stand-alone" generic courses, and what sorts of skills students should be learning in these courses, there is virtually no disagreement over the need to help American students improve how they think. Both George Bush, the elder, and Bill Clinton, when he was governor, supported the national education goal for higher education that declared that it was a national priority to enhance critical thinking in

college students, although I might add that this national priority was never funded. It was a great idea that both Democrats and Republicans agreed upon, until it was time to pay for it, causing some to cynically wonder if politicians really want a thinking public.

In his award-winning book, Earl Hunt (1995) examined the skills that will be needed by our workforce in the early decades of this century and asks, "Will we be smart enough?" The way we answer this question will determine the quality of life that we and our children can expect to live, as well as the future of our country and our planet. The most important reason for making the enhancement of critical thinking skills the primary objective of education is that the world is changing at an accelerating rate. The workforce is one critical place where we can witness the dizzying pace of change. There is an increased demand for a new type of worker—with a new job category, which has been dubbed the "knowledge worker" or the "symbol analyst" (a term that is used by the United States Secretary of Labor), to describe someone who can carry out multi-step operations, manipulate abstract and complex symbols and ideas, acquire new information efficiently, and remain flexible enough to recognize the need for continuing change and for new paradigms for life-long learning.

Workers in almost every job category can expect to face novel problems because the nature of the workplace is changing repeatedly. Familiar responses no longer work and even newly acquired ones won't work for long. The information explosion is yet another reason why we need to provide specific instruction in thinking. We now have an incredible wealth of information available, quite literally at our fingertips, via the internet and other remote services with only a few minutes of "search time" on the computer. The sheer quantity of data that is available is overwhelming. Relevant, credible information has to be selected, interpreted, digested, evaluated, learned, and applied or it is of no more use on a computer screen than it is on a distant library shelf. If we cannot think intelligently about the myriad of issues that confront us, then we are in danger of having all of the answers, but still not knowing what they mean. The twin abilities of knowing how to learn and knowing how to think clearly about the rapidly proliferating information that they will be required to deal with will provide the best education for citizens of the 21st century.

Let me explain what I mean by the term "critical thinking" and suggest that we use this as a working definition:

The term **critical thinking** is the use of those cognitive skills or strategies that increase the probability of a desirable outcome. It is purposeful, reasoned, and goal-directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. Critical thinkers use these skills appropriately, without prompting, and usually with conscious intent, in a variety of settings. That is, they are predisposed to think critically. When we think critically, we are evaluating the outcomes of our thought processes—how good a decision is or how well a problem is solved. Critical thinking also involves

evaluating the thinking process—the reasoning that went into the conclusion we've arrived at or the kinds of factors considered in making a decision. (Halpern, 1996, 1998)

In the term "critical thinking," the word "critical" is not meant to imply "finding fault," as it might be used in a pejorative way to describe someone who is always making negative comments. It is used instead in the sense of "critical" that involves evaluation or judgment, ideally with the goal of providing useful and accurate feedback that serves to improve the thinking process.

Here is a list of generic skills that can be important in many situations:

A critical thinker can:

- Recognize that a problem exists
- Develop an orderly planful approach so that tasks are prioritized and problems are recognized as differing with regard to how serious and urgent they are
- Use the metacognitive knowledge that allows novices to monitor their own performance and to decide when additional help is needed
- Develop an openness to a variety of solutions, even novel ones
- Generate a reasoned method for selecting among several possible courses of actions
- Give reasons for choices as well as varying the style and amount of detail in explanations depending on who is receiving the information
- Recall relevant information when it is needed
- Use skills for learning new techniques efficiently and relating new knowledge to information that was previously learned
- Use numerical information, including the ability to think probabilistically and express thoughts numerically
- Understand basic research principles
- Demonstrate an advanced ability to read and write complex prose
- Present a coherent and persuasive argument on a controversial, contemporary topic
- Provide complex instructions in language that is appropriate for the audience
- Use matrices and other diagrams for communication
- Synthesize information from a variety of sources
- Determine credibility and use this information in formulating and communicating decisions.

Critical thinking instruction is predicated on two assumptions: (1) that there are clearly identifiable and definable thinking skills which students can be taught to recognize and apply appropriately, and (2) if recognized and applied, the students will be more effective thinkers.

I can probably guess what you are thinking. This is a great list of critical thinking skills and you could easily add more, but is there good evidence that adults will improve in these skill areas in ways that transfer to novel situations and endure beyond the term of instruction when they are specifically taught these skills. First, there is no reason to believe that the ability to think critically can't be improved. Most students improve in their ability to write after taking

coursework in writing; similarly, most students become better at oral communication after appropriate instruction, and so on for math and other cognitive skill areas. We now have a sufficiently large body of research that shows that it is possible to teach in ways that help students become better thinkers and that these skills transfer to novel situations when we teach specifically for transfer.

TYPES OF EVIDENCE

- "Blind" evaluations of programs designed to enhance thinking skills (e.g., the Venezuela project; Herrnstein, Nickerson, de Sanchez, & Swets, 1986)
- Student self reports (weak evidence, but students believe that they have improved; Block, 1985)
- Gains in cognitive growth and development (e.g., Piagetian tasks that measure cognitive stages; Fox, Marsh, & Crandall, 1983; Kosonen & Winne, 1995)
- More expert-like mental representations following instruction (relative to control groups; Shoenfeld & Hermann, 1982)
- Tests of cognitive skills (e.g., standardized tests for critical thinking; Facione, 1991; Mc Bride, 1996)
- Spontaneous and uncued transfer (e.g., call students at home months after the class is completed under the guise of a survey; Fong, Krantz, & Nisbett, 1993)
- Inductive reasoning tasks were taught to college students using realistic scenarios from many different domains. The authors conclude that critical thinking is "a skill" and that "it is transferable" (Jepson, Krantz, & Nisbett, 1993, p. 82).

Traditionally, instruction in how to think has been a neglected component in American education. Students were more often taught what to think than how to think, or in a jargon you may be more familiar with, the emphasis has been on declarative knowledge rather than the procedural knowledge needed for effective thinking—instruction on how to approach problems, how to generate and test hypotheses, how to comprehend difficult text, how to make causal inferences. Yet we are expected to instruct our own students in the art and the skill of thinking. Education in most of the disciplines has primarily been concerned with presenting students with the "facts" on a variety of topics—the "knowing that"—while offering little on how to utilize this information or how to discover facts on their own—the "knowing how."

Often faculty will tell me "Of course I teach critical thinking. What kind of thinking do you think I teach—noncritical thinking?" Examples of noncritical thinking are the rote applications of rules, verbatim memory, or nondirected thinking such as day dreaming. Let me give you an example from psychology, my own area. It is common in most courses in developmental psychology to have students learn Piaget's stages of cognitive development and list them in order by name and age on an exam. Certainly this is key information in a class in developmental psychology, and students need to know it, but too often the learning ends there—students cannot understand any implications from this work or use it in any meaningful way beyond repetition. These common practices are not teaching for thinking.

The idea of critical thinking instruction is that the skills and attitudes of critical thinking are deliberately and self-consciously taught. It is the difference between requiring students to engage in critical thinking activities and teaching them how. For example, a popular assignment in many classes is to have students compare several events or theories. A critical thinking lesson would explicitly teach how to make comparisons. The idea of having specialized classes in critical thinking was not to remove critical thinking from other classes, but to provide a course where instruction in how to think critically is the key focus with the idea of using multiple types of examples to help with the spontaneous transfer of learning, much in the way we have classes that teach writing or speaking with the goal of getting the skills of good writing and speaking to transfer to other settings.

The model that I have proposed for critical thinking instruction consists of four parts:

A FOUR-PART MODEL FOR IMPROVING CRITICAL THINKING

1. Explicitly teach the skills of critical thinking
2. Develop the disposition for effortful thinking and learning
3. Direct learning activities in ways that increase the probability of transcontextual transfer (structure training)
4. Make metacognitive monitoring explicit and overt.

A SKILLS APPROACH TO CRITICAL THINKING

I have proposed a taxonomy of critical thinking skills. The taxonomy is not meant to be an exhaustive list—it is just a starting point for a serious discussion of what we mean by critical thinking skills and how we can best define them so that they are meaningful to a broad audience. As you can probably guess, I have been working on the development of a test of critical thinking based on this taxonomy. Skill level in each category can be assessed separately, in addition to an overall score. Other taxonomies are possible and a legitimate case can be made for alternative groupings or adding other skills and deleting some of those that are listed. This is not meant to be ***the*** definitive list of critical thinking skills. Rather, it is proposed as a concrete starting place for the task of deciding what we want college graduates who are entering the workforce to know and be able to do so that they can compete and cooperate in the world's market place and function as effective citizens in a complex democratic community.

Here are the five category headings for organizing college-level critical thinking skills:

1. Verbal Reasoning Skills

   The skills listed under this rubric include those that are needed to comprehend and defend against the persuasive techniques that are embedded in everyday language (also known as natural language). Thinking and language are closely tied constructs, and the skills included in this section recognize the reciprocal relationship between

language and thought in which an individual's thoughts determine the language used to express them, and the language that is used shapes the thoughts.

2. Argument Analysis Skills

   An argument is a set of statements with at least one conclusion and one reason that supports the conclusion. In real life settings, arguments are complex with reasons that run counter to the conclusion, stated and unstated assumptions, irrelevant information, and intermediate steps. Arguments are found in commercials, political speeches, textbooks, and anywhere else where reasons are presented in an attempt to get the reader or listener to believe that the conclusion is true. The skills of identifying conclusions, rating the quality of reasons, and determining the overall strength of an argument should be sharpened in college course work.

3. Skills in Thinking as Hypothesis Testing

   The rationale for this category is that much of our day-to-day thinking is like the scientific method of hypothesis testing. In many of our everyday interactions, people function like intuitive scientists in order to explain, predict, and control the events in their life. The skills used in thinking as hypothesis testing are the same ones that are used in scientific reasoning—the accumulation of observations, formulation of beliefs or hypotheses, and then using the information collected to decide if it confirms or disconfirms the hypotheses.

4. Using Likelihood and Uncertainty

   Because very few events in life can be known with certainty, the correct use of probability and likelihood plays a critical role in almost every decision. Huff's (1954) tiny, popular book *How To Lie With Statistics* is still widely quoted because it explains how easy it is to mislead someone who does not understand basic concepts in probability. The critical thinking skills that are subsumed under this heading are an important dimension of a college-level critical thinking taxonomy.

5. Decision Making and Problem Solving Skills

   In some sense, all of the critical thinking skills are used to make decisions and solve problems, but the ones that are included here involve the generation and selection of alternatives and judging among them. Many of these skills are especially useful in quantitative reasoning problems.

Taken together these five categories define an organizational rubric for a skills approach to critical thinking. They have face validity and can be easily communicated to the general public and students and offer one possible answer to the question of what college students need to know and be able to do to compete and cooperate in the world's marketplace and function as effective citizens in a democratic society.

DISPOSITIONS FOR EFFORTFUL THINKING AND LEARNING

It is important to separate the disposition or willingness to think critically from the ability to think critically. Some people may have excellent critical thinking skills and may recognize when they are needed, but they may also choose not to engage in the effortful process of using them. This is the distinction between what people can do and what they actually do in real world contexts. Good instructional programs help learners decide when to make the necessary mental investment in critical thinking and when a problem or argument is not worth it.

Dispositions for effortful thinking and learning:

- Willingness to engage in and persist at a complex task
- Conscious use of plans and suppression of impulsive activity
- Flexibility or open-mindedness
- Willingness to abandon nonproductive strategies in attempts to self-correct
- An awareness of social realities that need to be overcome so that thought can become actions.

TRANSFER OF TRAINING

In teaching for thinking the goal is to have students not only understand and successfully use a particular skill when it is being taught but to also be able to recognize when that skill will be appropriate in a novel situation. This is the Achilles' heel of transfer. The problem in learning thinking skills that are needed in multiple contexts is that there are no obvious cues in the context to trigger the recall of the thinking skill. Students need to create the recall cues from the structural aspects of the problem or argument, so that when the structural aspects are present, they can serve as cues for retrieval. A similar point was made by Hummel and Holyoak (1997) who said, "**First, thinking is structure sensitive. Reasoning, problem solving, and learning... depend on a capacity to code and manipulate relational knowledge.**"

When critical thinking skills are taught so that they transfer appropriately and spontaneously, students learn to focus on the structure so the underlying characteristics become salient instead of the domain specific surface characteristics. There is an old saying in psychology that "the head remembers what it does." It is important to design learning activities so that the skills are encoded in a way that they will facilitate their recall in novel situations if you want to teach for transfer. It is what the learner does that determines what gets learned, not what the teacher does.

After context-rich information is provided, learners are asked to perform certain tasks or answer carefully crafted questions. Here are some examples of relevant tasks and questions that require learners to attend to structural aspects of the problem or argument:

- Draw a diagram or other graphic display that organizes the information
- What additional information would you want before answering the question?

- Explain why you selected a particular multiple choice alternative. Which is second best? Why?
- State the problem in at least two ways
- Which information is most important? Which information is least important? Why?
- Categorize the findings in a meaningful way
- List two solutions for the problem
- What is wrong with an assertion that was made in the question?
- Present two reasons that support the conclusion and two reasons that do not support the conclusion
- Identify the type of persuasive technique being used
- What two actions would you take to improve the design of the study that was described?

METACOGNITIVE MONITORING

Metacognition refers to our knowledge of what we know (or what we know about what we know) and the use of this knowledge to direct further learning activities. When engaging in critical thinking, students need to monitor their thinking process, check whether progress is being made toward an appropriate goal, ensure accuracy, and make decisions about the use of time and mental effort. Students can become better thinkers and learners by developing the habit of monitoring their understanding and by judging the quality of their learning. It is the executive or "boss" function that guides how adults use different learning strategies and make decisions about the allocation of limited cognitive resources. Numerous studies have found that good learners and thinkers engage in more metacognitive activities than poor learners and thinkers, and that the skills and attitudes of metacognitive activities can be taught and learned so that students can direct their own learning strategies and make judgments about how much effort to allocate to a cognitive task.

For example, when students are required to provide reasons and evidence to support a conclusion and counterreasons and conflicting evidence, they must focus on the quality of the thinking that went into a decision. The giving of reasons forces thinkers to "tickle their memory." By this I mean they have to access information stored in memory. They also have to consider both positive and negative evidence. It is well documented that we tend to weigh evidence much more heavily when it favors a belief that we hold over evidence that disconfirms a personal belief.

There are numerous experimental demonstrations of this bias for confirming evidence. For example, in one study, college students were asked to write a response to a controversial question in which they argued for one side or the other (Lord, Ross & Lepper, 1979). Students were then given the results of experimental studies that supported a "middle of the road" point of view. After reading the balanced review, subjects who favored the "pro" position of the controversial question believed that the objectively neutral paper supported the "pro" position. Similarly, students who read the "con" position and then read the same objectively balanced

paper believed that it favored the "con" position. Instead of bringing the two sides closer together, as might have been expected, the balanced paper drove them farther apart. Each position focused on the information that supported their own point of view and judged the evidence that ran counter to their favored position to be weak. This same finding has been found with all sorts of subject pools, including NASA scientists who favor evidence and arguments that support their preferred hypothesis over one that does not (Mynatt, Doherty, & Tweney, 1978). Just telling people that we tend to be overconfident and to rely on confirming evidence, so don't do it, doesn't work. Knowing that people tend to be overconfident does not help people to become more accurate, nor does knowledge of the confirmation bias help people to overcome it. Is it any wonder why it is so difficult to get people to assess controversial issues in a fair-minded manner? These sorts of experimental results show that the giving and assessing of reasons can have beneficial results that improve the thinking process.

Sometimes, college faculty unwittingly encourage the exact opposite of what we want students to learn. Consider, for example, many writing assignments where we ask students to take a position on a controversial issue in psychology and then to write a position paper. This is exactly the sort of learning activity that would strengthen the bias to seek and consider only confirming evidence. Instead, we need to help students understand and be able to explain evidence on two or more sides of an issue, such as the evidence for and against evolutionary hypotheses of mate selection or for and against the idea that parents are important influences on their children. We want to teach students to gather and assess evidence to determine the best conclusion or conclusions and not start with what they believe is true and consider only supporting evidence.

I hope that this brief overview to the applications of cognitive science to critical thinking instruction has convinced you that education for thinking should be a major objective of education. When we consider that many of the today's young adults will be working at jobs that do not exist today and not even science fiction writers can imagine and living well into the decades beginning with 2060 and 2070, it seems clear that the ability to think critically and the disposition to engage in the effortful process of thinking are the most critical components of their education.

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A FRAMEWORK FOR CRITICAL THINKING RESEARCH AND TRAINING

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My job today is to present to you the results of research we have been conducting at Anacapa Sciences over the past nine months. The main product of this research has been a framework or model we developed for critical thinking (CT). We developed the model with the goal of directing and guiding research on CT, particularly research investigating training issues. However, it serves the additional purpose of providing a common vocabulary of CT that we can use throughout the workshop to discuss our ideas.

Before I begin my presentation, I'd like to acknowledge the contributions of several individuals who have greatly influenced this research. First, my colleague at Anacapa Sciences, Alan Spiker, deserves equal credit and blame for the ideas I will present to you today. The framework you will hear about today is the product of such a truly collaborative effort that it's difficult to attribute responsibility for any particular idea. Second, this work was greatly enhanced by the help of the officers of the First Cavalry Division at Fort Hood, Texas. Third, this research would not have been possible without the support we received from the Army Research Institute. In particular, I'd like to acknowledge the significant contributions and guidance of Dr. Sharon Riedel.

I'd like to begin by giving you a roadmap for my talk today. I will briefly discuss historical conceptions of CT because I think our framework is best understood when placed in front of the backdrop of other researchers' thoughts. We stand on the shoulders of those researchers to perhaps reach a little farther in our understanding of critical thinking. I will then turn to a very brief discussion of how we went about developing our model of CT. This will also help you to understand the framework we've developed. I'll then discuss the model itself in some detail, its contributions and limitations, its relationship to command and control, and its implications for training CT in the military.

HISTORICAL CONCEPTIONS OF CRITICAL THINKING

It is clear that many commercial and academic domains regard critical thinking as an important characteristic they would like their members to possess. For example, the development of CT skills in students who attend public educational institutions has become a central component of the United States' national education goals. In the military, research on leadership has identified the need for training programs that promote better thinking to improve battle command decision making, and several courses have been developed and implemented. In the public and business sectors, the National League for Nursing has required the demonstration of CT in graduates of nursing education programs, DeVry vocational programs now assess the thinking skills of their students, and many U.S. corporations now provide employees with

training in thinking skills. In short, increasing CT skills in U.S. citizens has become a significant goal within government, public, and corporate arenas.

Why has CT received so much attention from such a diverse group of interests? There are, perhaps, two related answers to this question. First, society is experiencing an increased need for intellectual skills due to demands created by developing technologies. In the past 20 years, our economic and social systems have become dependent on complex technologies, with information becoming either a primary or intermediate product that must be processed to serve decision making. One process that works on information is reasoning, which must be rational and purposeful to be effective. When information is incomplete, uncertain, or unreliable, the ability to evaluate its quality becomes paramount to competent decision-making. Hence, rational CT is viewed as a skill necessary to the manipulation of information, especially when the information is degraded. Greater reliance on information will necessitate greater reliance on CT skills. All areas of society are experiencing increases in available information and a corresponding greater demand on intellectual processing. In some domains, however, technological development has increased the available information to such a high degree that job demands may soon be exceeding current skill levels. Second, a number of domains (e.g., nursing, business, military leadership) have recognized the need to improve CT of personnel whose cognitive skills they suspect are deficient.

Feeding and supporting this increased interest, CT has also become a recognized construct in philosophy, education, and, to a lesser degree, psychology. If one searches the education, philosophy, and psychology literature databases for the term "critical thinking," one will obtain an enormous number of citations in the first two disciplines, but relatively few in the third. Hence, it appears that the concept of CT is not one that has been generated by psychology, but is an issue that has primarily concerned philosophers and educators. This makes a lot of sense because thinking is the primary activity one engages in when philosophizing and improving thinking capabilities is a primary activity in which educators engage. Hence, the construct of CT has been developed by several fields, each with its own set of motivations, purposes, and biases. An unfortunate fact is that construct development has been largely based on philosophical arguments. Very little empirical research has been designed to develop the theoretical construct of CT. Compared to the extensive development of the concept of intelligence, for example, development of CT as a theoretical entity has received almost no empirical attention.

Perhaps because of the different motivations of the various fields who have contributed to the conceptual development of CT, or perhaps because of the lack of empirical grounding of the concept, the present theoretical state of the field is highly fragmented. Although one can extract some general themes from the literature, there is no consensus among researchers as to the concept's meaning. There appear to be as many definitions of CT as there are researchers who study it. The American Philosophical Association attempted to provide some guidance to CT

research by developing a consensus definition derived using the Delphi technique on 46 critical thinking experts. However, the resulting lengthy definition has not adequately provided the direction intended or required. Since 1990, when the APA offered their comprehensive definition, authors who consider CT still approach the topic using their own definition.

In the absence of a dominant theory, one might consider the three most frequently used assessment instruments for evaluating CT (the Watson-Glaser Critical Thinking Appraisal, the California Critical Thinking Skills Test, and the Cornell Critical Thinking Instrument) to be defacto models of CT. Certainly, they provide the most commonly accepted operational definition of CT in the research literature. However, studies have shown the tests to have low internal reliability, a lack of comparability among forms, and corresponding poor construct validity. Just as significant, it may be that these instruments are simply tapping variability in performance that may just as well be explained by intelligence and/or achievement tests. For this reason, we are left with a situation that produces great difficulty in communicating what we mean when we use the term "critical thinking."

Despite differences among conceptions of CT, examination of the literature reveals a modest amount of overlap and redundancy. Among these definitions, several "themes" repeat themselves, of which we identify six. For example, many, but not all, theorists regard the ability to use *reasoning* and *informal applied logic* as central to CT. *Judgment* or *evaluation* of information or a source is a second common theme. Some theorists see judgment as the "critical" component of CT. Others make no mention of judgment in their definitions or discussions. Other themes seem to describe a state of mind rather than a skill or ability. For example, several theorists describe CT as an attitude or activity that is *reflective* or *questioning*. A few theorists describe CT as a recursive, interactive activity that involves *meta-cognition* while others simply note that CT involves some sort of *mental process*. Those who emphasize its meta-cognitive nature view CT as "thinking about thinking that serves to improve thinking." Finally, several definitions explicitly emphasize the *purposeful* nature of CT. For these theorists, CT is not a series of aimless, random thoughts. It is distinguished from regular thinking in its goal-directed nature that is applied to serve a purpose.

We must conclude that CT can be, and has been, defined in a number of ways. If one chooses to bound the definition narrowly, then most authors regard CT as the evaluation or judgment of information and sources. If one chooses to define CT broadly, it typically becomes all those mental processes that are purposeful. Or, as the APA would suggest, CT is thinking that is broadly characterized by the themes we have discussed. We, however, take a different approach to defining CT, one that embraces an empirical perspective. Our emphasis on empirical evidence serves to de-emphasize analytic definitions of CT and subjects it to scientific testing. We believe it is time to put away matters of definition and move on to the measurement and testing of CT, for that is where the greatest gains in knowledge and application will be. In summary, our position is that the utility of a definition depends on its ability to generate research

that can lead to better training. Beyond these potential benefits, definitions will do little to further our understanding of CT.

A MODEL OF CT

In fact, more than definitions, what is needed to guide research and empirical testing is a model of CT. If we are interested in improving thinking, what part of CT should we focus on? What part should be trained? In short, while CT appears to possess great promise in increasing success in many domains, including battle command, a model is needed to guide training and evaluation. A guiding model will generate research to support training choices. It will also ensure that the training is complete, coherent, and consistent.

To meet these objectives, we set out to develop a model of CT that incorporates existing conceptions. We sought to synthesize ideas about CT to develop a model that was not so narrowly defined as to lose meaning but was also not so broad as to lose focus. Criteria were applied to ensure the model would be useful. For example, we sought to develop a model that would stimulate the collection of research data relevant not only to developing the concept of CT, but also to guide the training of CT. Because we were working in the context of battle command, we wanted to develop a model that would generate information that could be used to populate military training in CT. It was imperative that the model could be used to describe the thinking tasks army officers use in the context of their work, specifically, command and control.

The model was developed using a bottom-up process based on an extensive review of the educational, philosophical, and psychological literatures on CT. In our review, we coded and recorded any CT skill mentioned by an author. We also noted any subject, situational, stimulus, or moderating variable associated with CT. The information gleaned from the literature review provided critical input to develop a CT model, moving forward a very fragmented, but potentially useful, construct; however, we shaped the model through the use of a top-down process in which the identified skills and variables were organized to form a coherent picture of CT.

The resulting model is closely tied to conceptions of CT offered by authors in the fields of philosophy and education. For example, it organizes a number of variables that authors of CT have discussed, such as the influence of experience and knowledge, the relationship of CT to other mental tasks (e.g., decision making and problem solving), and the measurement of CT. However, it goes far beyond the largely *analytic* work conducted to date by providing a framework in which CT can be *empirically* investigated as a cognitive process. Up to this point, CT has been treated as a subject variable that can be measured and correlated with other variables of interest. We offer a model that allows empirical investigation of CT as a *psychological* construct. The most important contribution the model provides is direction for further research. It does so by generating testable hypotheses regarding entry into, and sustainment of, a CT "state." The model also generates hypotheses about CT's measurement, detection, and products.

We posit five essential elements to CT that distinguish it from typical treatments within the philosophy and education literature, as well as from earlier psychological treatments. First, we assume that CT is intimately linked to a set of initiating situational or contextual conditions that increase the likelihood that an individual will use his/her CT skills and thus enter the CT "state." In this way, we have *intentionally* distanced ourselves from a large segment of the educational and philosophical literature, which primarily treats CT as an individual difference measure. Our focus is on identifying the processes that are brought to action in response to *definable initiating conditions*, and our objective is a compact yet powerful theory of the skills required to process information deeply in response to measurable initiating conditions. Research on this theoretical tenet may serve to generate *a priori* predictions of when CT will occur.

Second, we treat CT as a highly stimulus-bound phenomenon in which deep cognitive processing is imposed on a circumscribed stimulus-information complex to assess its relevance, accuracy, completeness, clarity, logical consistency, and/or precision. By bounded, we mean that the to-be-processed stimulus can be physically isolated and specified in advance. This tenet affords investigation of external stimulus factors that govern entry into or maintenance of the CT "state."

Third, we consider CT to be truly time-limited, wherein an individual may execute the necessary skilled processes for only a few minutes (or less) before he/she must "come out" and assess the status of what has been accomplished. A likely reality is that CT processes are continually being interrupted in order to consult with others, view the consequences in the external world, or simply "take a break" from the mental effort. A ripe area for study will be to identify the stimulus and contextual conditions that precipitate these breaks and to develop countermeasures that serve to keep people longer in a CT state.

Fourth, we assume that engaging in CT processes has state-like consequences in which the individuals experience emotions, motivations, and other phenomenological experiences that are reportable. While the literature has made passing reference to CT as being "effortful" or "work," we propose that state properties are a vital aspect of CT as a phenomenon. In particular, negative experiential consequences of the state that seem to accompany CT would offer a plausible explanation as to why people do not engage in it more often. Besides the negative affect generated during CT, there may be other state-like properties of CT that might have implications for research. For example, it may be possible to correlate psychophysiological measures with CT occurrence.

Finally, in view of the previous four tenets described above, we believe CT can be subjected to experimental manipulation given proper controls. This is, perhaps, the most important outgrowth of our assumptions, as it implies one can manipulate the likelihood of CT through systematic changes in the stimulus and/or contextual conditions. This view stands in sharp contrast to the bulk of the literature that treats CT as a response measure and an indicator

of individual differences in which people's scores on some standardized test of CT are correlated with other subject characteristics.

Despite our caveats about definitions, we offer one for CT that summarizes our theoretical tenets. However, our definition should not be taken too seriously, for we believe the most fruitful definition will be operational and developed in the context of empirical study. *Critical thinking is a time-limited mode of deep processing that is goal-directed, stimulus-driven, and context-bound. Its constituent processes are tightly wound and the experiential consequences of being in the state are generally unpleasant.*

The opportunities for a CT episode are set in motion when a set of situational conditions arise that demand—or at least make it highly desirable—that the subject engage in deep processing to achieve a desired analysis of the stimulus information. Situational conditions are environmental factors that may include variables pertaining to the stimulus, task, and surrounding context. Situational conditions do not include subject variables, however. As shown in the model of CT depicted in Figure 1, two types of situational conditions are distinguished, defining and predictive. Defining situational conditions are ones that are necessary for entry into a CT episode. We posit that three *must* be present in the situation for entry into and maintenance of CT. These include (1) substantive information exists in the stimulus (there is information that requires processing); (2) the required activities cannot be executed by algorithmic methods, i.e., they are not procedural or routine; and (3) time is not severely limited, i.e., sufficient time is available to engage in CT. A set of *predictive* situational conditions is also posited. These are conditions that *increase the likelihood* an individual will enter into a CT episode. For example, situations where there is no single answer to a problem, or in which conflicting information is received, would tend to elicit a CT episode.

Besides the situational conditions, predisposing attitudes are posited that make the subject more or less likely to engage in CT processing. Predispositions are essentially subject variables that represent individual differences, whether *fixed* or *modifiable*, within the population of concern that are related to CT in a specific way. They influence the likelihood of a person entering into, or maintaining, a state of CT, and like situational conditions, they serve as input conditions for the use of CT skills (see Figure 1). They do not include predispositions that govern how well someone thinks critically, however.

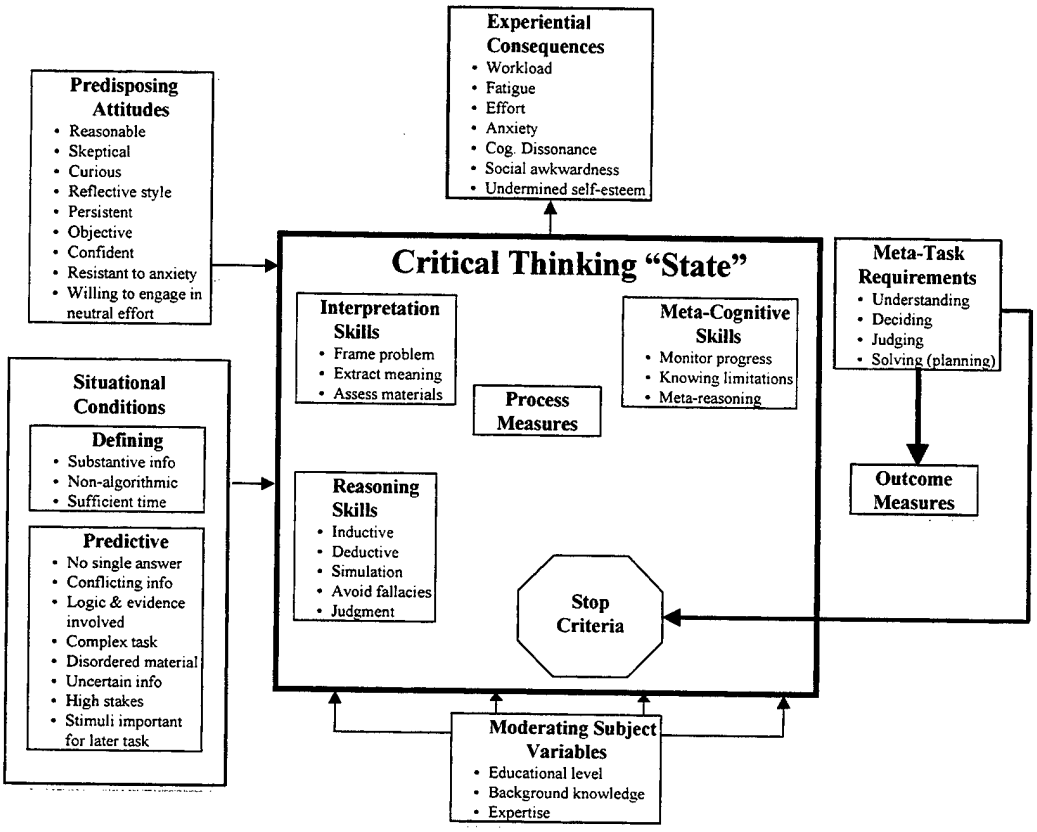

FIGURE 1: Depiction of CT Model

The model also incorporates a set of moderating variables representing individual difference factors that, while not directly or causally related to one's use of CT skills, might mitigate the effects of CT skills through interactions with other variables. Moderating variables are not part of the stimulus situation, but tend to reflect subject characteristics (e.g., domain expertise, recent experience, education) that would need to be considered when designing test procedures or forming subject groups. For example, highly experienced individuals may have a greater tendency to enter into and maintain CT, or they may have the requisite knowledge to use certain CT skills.

Figure 1 also shows four meta-tasks that serve to delineate the task requirements and general purpose of a CT episode. They provide a higher order structure for specific tasks, which themselves are part of the theory. In a strict sense, the meta-task requirements of the episode form part of the stimulus context and thus dictate the specific response that will be required to successfully end a given CT "episode." CT skills serve the purpose of completing tasks and meta-tasks; hence, in Figure 1 the relationship between these two theoretical constructs is

depicted as a directional one where the performance of CT skills serves as input to tasks and meta-tasks.

As noted above, an interesting corollary to the present approach is the postulation that individuals who engage in CT for any substantive length of time experience affective reactions that are, by and large, negative. Consistent with the CT literature, we hypothesize that individuals who maintain CT do so in part because they are able to maintain a neutral state. In other words, we do not suggest there are positive intrinsic rewards associated with the *process* of CT, although there are probably positive outcomes that result from the application of CT. Several affective reactions are specified, the predominant byproduct being one of mental fatigue or workload. In Figure 1, experiential consequences are depicted as a byproduct of performing CT skills, which are shown within the central region labeled "Critical Thinking State."

The inner part of the figure depicts blocks of CT skills that offer a scheme for organizing the myriad skills and processes that are involved when an individual engages in CT and a model of the types of processes that one engages in when entering CT. Once in the state, an individual will initiate CT processes that can be categorized into one of three stages. As shown in Figure 1, these correspond to interpretation of the stimulus materials, reasoning with some facet of the extracted information, and then engaging in some type of meta-cognitive monitoring that links the CT process with other CT episodes, other aspects of the environment, or the meta-task demands. Comparison of outcomes to a set of stop criteria will lead to initiation of the required decision, a judgment, understanding of the material, a solution, or, perhaps, another cycle of CT processing.

The separation of CT processes and skills into the three stages is a preliminary attempt to model CT as a set of cognitive processes. However, strict unambiguous separation among skills is difficult at this point, and it is unclear whether this particular partitioning of skills is the most useful. Tables 1, 2, and 3 offer a complete list of skills incorporated into the model.

INTERPRETATION SKILLS		
SKILL GROUP	**COGNITIVE PROCESS AREA**	**SKILL**
Interpretation Skills	Framing the problem	Redefine problem or goal so it can be measured
		Break overall goal into sub-goals
		Seek clear statement of question
	Extracting meaning from material	Recognize central thesis in material
		Distinguish relevant from irrelevant information
		Extract meaning from context
		Discern when term is being used with different meanings
		Construct story that ties all information elements together in plausible way
	Assess or evaluate materials for consistency, clarity, validity and completeness	Identify assumptions and challenge their validity
		Identify and assess validity of unstated assumptions
		Identify missing information
		Identify emotional and misleading language
		Detect missing operational definitions
		Detect ambiguities
		Detect inconsistencies
		Distinguish among facts, opinions
		Assess credibility of observation or information
		Distinguish among conclusions, assumptions, and hypotheses

TABLE 1

REASONING SKILLS		
SKILL GROUP	**COGNITIVE PROCESS AREA**	**SKILL**
Reasoning Skills	Formal Reasoning	Distinguish between inductive and deductive reasoning
		Use deductive logic to draw conclusions from premises
		Reason dialogically to identify and compare perspectives
		Reason dialectically to evaluate points of view
		Distinguish between logically valid and invalid inferences
		Determine whether argument depends on an ambiguity
		Assess strength of conclusion or argument
		Apply general principles to specific cases
		Identify transitive relationships
	Informal Reasoning	Extrapolate from observations within reasonable limits
		Redefine sweeping generalizations and oversimplifications
		Generalize from specific instances to broader classes
		Determine whether a simple generalization is warranted
		Identify and avoid ad hominem reasoning
		Identify and avoid reasoning based on false dichotomy
		Identify and avoid reasoning based on guilt by association
		Identify and avoid reasoning based on emotional appeal
		Distinguish between validity of a belief and intensity with which it is held
		Draw inductive inference from observations
		Base reasoning on observations because they are more credible than inferences based on them
		Identify and avoid hindsight bias
	Simulation	Mentally simulate plans to see if they achieve goals
		Mentally generate a structure of possibilities
		Mentally simulate probable consequences of an alternative
		Develop and use a mental model
	Judgment	Judge the "best explanation" of a set of facts
		Make a reasoned value judgment by considering background, consequences, principles
		Judge when argument is reasoned vs rationalized
		Judge when evidence is insufficient to warrant conclusion
		Judge when causal claims can and can't be made

TABLE 2

META COGNITIVE SKILLS		
SKILL GROUP	**COGNITIVE PROCESS AREA**	**SKILL**
Meta-cognitive Skills	Monitor progress of critical thinking	Perform means-ends analysis to check status
		Monitor events for consistency with expectations
		Monitor relevancy of thinking to its main purpose
		Monitor own understanding of problem
	Monitor one's own limitations	Recognize fallibility and likely bias of own opinion
		Assess quality of own judgment based on kind of judgment being made
		Assess quality of own judgment based on indicators related to criteria
		Identify own assumptions and biases
	Strategic reasoning	Support general assertions with specific facts
		Frame decision in alternative ways
		Generate alternative explanations or interpretations
		Explore the implications of beliefs, arguments, or theories
		Adopt multiple perspectives
		Use analogous arguments to bolster conclusion
		Transfer learning from analogous situations to new contexts
		Reason from starting point with which one disagrees
		Seek disconfirming evidence
		Take total situation into account
		Decide when to seek information based on its value and cost
		Decide when to consider new information or evidence based on its support or refutation of conclusions Reason by taking representative samples

TABLE 3

CRITICAL THINKING IN COMMAND AND CONTROL

The real test for any model is the development and evaluation of models that instantiate the model's elements in real-world applications. Hence, an important component of our research has been to determine if a model of CT could be developed for the domain of Army command and control (C^2). We attempted to validate the content of the model by conducting a combined survey and after-action interview with Army subject matter experts at Ft. Hood, Texas. The focus of the survey was to ascertain whether the model adequately delineated CT skills, exemplified them in terms understandable to Army officers, and represented their relationship to battle command tasks in meaningful ways. A survey instrument was developed and administered to address these questions. After-action interviews were also conducted to obtain a better understanding of particular survey responses.

The results of the survey and interviews are represented in Figure 2. Officers noted that the predisposing attitudes of being persistent, confident, withholding judgment, being reasonable and willing to expend effort were critical to C^2. They also confirmed that defining situational conditions necessary for CT were that the task be non-algorithmic, there must be sufficient time for thinking to occur, and there must be sufficient content in the task. The predictive situational conditions they identified were that the situation presented conflicting information and that the stakes were high and therefore motivating. The officers also noted that the resolution of the situation could be achieved with more than one solution. The key predisposing attitudes, defining situational characteristics, and battle C^2 tasks identified by the survey respondents were incorporated into the model.

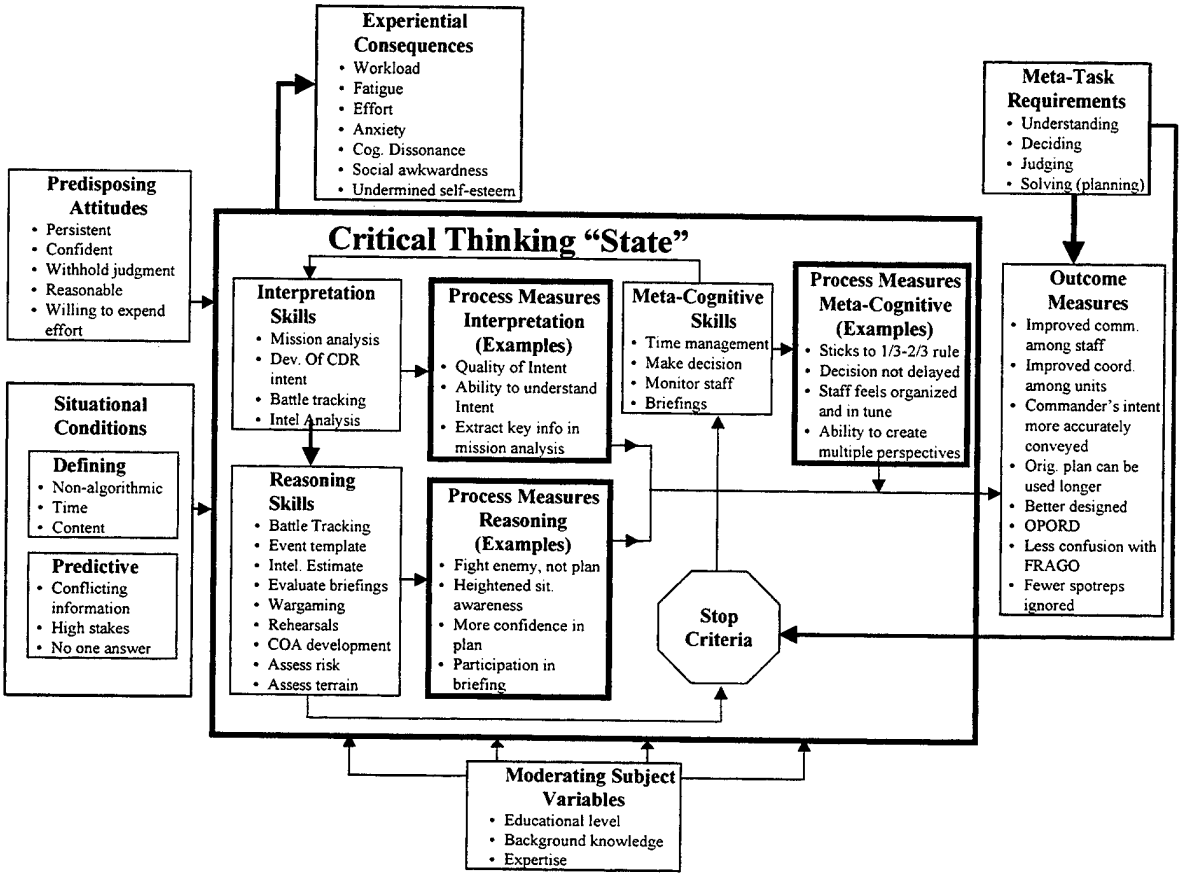

FIGURE 2: Depiction of CT Model Instantiated in C^2 Tasks

Survey respondents indicated a set of C^2 tasks for each set of CT skills. For example, mission analysis, development of commander's intent, interpreting the commander's intent, battle tracking, and intelligence analysis were all thought to heavily tap interpretation skills. Figure 2 shows the C^2 tasks associated with reasoning and meta-cognitive skills as well. The results indicated that meta-task requirements for CT include only decision making and solution (planning). The strong need in battle command to make decisions and execute actions rules out tasks in which the sole purpose is to simply understand or to make a judgment of quality. Figure 2 also lists some example outcome measures that could be used to assess the ultimate products created from variation in CT performance.

IMPLICATIONS FOR TRAINING

The model we have developed to explain CT has specific implications regarding its training. For example, if CT is stimulus driven, then training should include multiple scenarios that are information-rich. The scenarios should promote the necessary CT skills and advanced training principles, such as deliberate practice, should be used to structure education. If CT is

stimulus driven, research is necessary to identify the content parameters of the stimuli that are most effective at eliciting CT episodes. The goal of training should be to maximize transfer of CT skills to the unpredictable battlefield environment. For this to happen, the stimulus dimensions of the battlefield related to CT must be identified and utilized within a training environment.

If CT is multidimensional, as indicated by the set of CT skills provided in the model, a variety of training formats will be required. Each dimension of CT is likely to require a different approach. The Web may provide the flexibility necessary to house varied training formats. It can also provide the opportunity for self-paced practice, which is likely to be necessary because of CT's multidimensional nature. This aspect of CT may also require that instructors take the role of a coach or tutor, providing guidance as necessary and monitoring progress. Finally, team training may be needed for skills that emerge in the context of a group.

If CT is fundamentally cognitive, a cognitive task analysis will be necessary to guide instructional development. In fact, multiple cognitive task analysis paradigms will be necessary to capture the elemental cognitive functions that determine CT.

If CT is a learned skill, curricula will vary based on rank. Training must also consider the student's learning curve. Scenarios will grow in complexity, as will performance expectations and evaluation standards. Research is needed to determine how CT increases with experience. Research is also needed to develop innovative training techniques because there is little extant empirical research.

CONTRIBUTIONS AND LIMITATIONS OF THE MODEL

To conclude my talk today, I'd like to address the contributions our model makes to current thinking about CT, as well as its limitations. We believe the most important benefit the model offers is that it affords and lays the groundwork for empirical testing of CT. Today, we've discussed just a few of the testable predictions generated by the model. Hypotheses concerning predispositions, defining and predictive situational factors, stimulus dimensions, moderating variables such as expertise, meta-tasks such as decision making, and particular CT skills can all be evaluated in the context of a guiding and organizing framework. We encourage other researchers to also evaluate the core tenets of the model. Further empirical research guided by this nascent model will serve to increase our knowledge of CT and develop better theories grounded in real world phenomena.

A second major contribution of the model, if adopted by the research community, is that it provides a common vocabulary for discussing CT. Because the field is so fragmented and because most studies do not provide empirical data that would incorporate operational definitions, it is very difficult to determine if authors are really talking about the same construct when they speak of CT. Hence, we hope the model will help to synthesize and organize multiple perspectives, thereby incorporating and embracing highly diverse approaches to defining CT.

I now turn to some of the model's limitations. Some may see the boundaries set on CT by the model as exclusive of important conceptions or skills. Although the model uses a broad definition of CT that is very inclusive, it may exclude some notions. For this reason, some may be dissatisfied with our approach. On the other hand, others who wish to limit CT to critical evaluation and judgment may regard our rather inclusive model as too broadly specified. We believe that, ultimately, empirical phenomena will serve to identify the most appropriate and useful boundaries for a model of CT.

Despite our stated empirical approach to develop CT as a psychological construct, it is somewhat ironic that the model is currently untested. We see this as the model's most important, although hopefully temporary, limitation.

ADDENDUM: ADDITIONAL RESEARCH ISSUES

Following our presentation, workshop attendees were encouraged to identify additional research issues that might be investigated regarding CT and its development within the military. What follows is a brief summary of the recommendations provided by the workshop participants.

In general, workshop participants were interested in teaching methods for increasing CT within teams. Many tasks carried out by Army officers occur in a team context where resources, information, and task products are shared and interdependent. Therefore, it makes sense that the integrated workings, roles, and interrelationships of the commander and his staff may affect elements of CT. There are currently no known studies of CT within a team context; hence, this is a ripe area for future research.

Perhaps the most needed research concerning CT is its measurement. As previously noted, extant instruments are limited to discriminating individual differences based on only a few of the many skill dimensions CT supposedly incorporates. Workshop participants noted that CT measurement is a very complex endeavor in part because it is difficult to identify true CT as distinct from after-the-fact rationalization. Any verbal justification of a decision, for example, could reflect the actual thinking that an individual used to complete the task, or it could simply be a fabricated, satisfying "story" that fulfills the need to explain the decision. The challenge for future research in the measurement of CT will be to reliably detect true CT and distinguish it from rationalization.

Making the measurement situation even more problematic is the demonstrated lack of reliability of the existing instruments' scales and forms. Therefore, better measurement techniques are needed to capture CT as a mental process and "state" as proposed by the model, and to evaluate the quality of CT reliably.

Issues regarding the training of CT should also be investigated in future research. Perhaps the key issue that has interested educational researchers for many years now is still the most important training issue: Do increases in CT obtained from training in one domain transfer to other domains? Workshop participants asked the following related question: Is it better to

infuse the training of CT throughout the Army's curriculum (or at least in certain training, such as the Command General Staff Officer Course) or should it be taught as a separate course? Should CT be taught in the abstract, in hope of increasing the likelihood of transfer, educating students in the principles of argument evaluation, and the identification of assumptions for example, or, should CT be taught in the context of a combat domain? Should CT be taught overtly such that students know they are being instructed in methods that would ostensibly improve their thinking, or, should training that would increase thinking be delivered to students, but veiled in the guise of material of the content domain? It is possible that awareness of thinking is actually detrimental to thinking; so, does awareness of CT skills improve performance or will it backslide? Instructional developers find these issues to be continual problems for the design of their courses.

A final set of research questions concerned the implementation of CT within the Army. Some workshop participants questioned whether CT is even useful or valid for the military. On the other hand, some questioned whether the Military Decision Making Process (MDMP) is still appropriate for an Army that is digitized, and facing more and more ill-specified situations that require adaptation and novel solutions. CT's role in the context of these changes the army is currently facing is another issue to be considered in future research.

ADDENDUM: SUGGESTED CHANGES TO MODEL

In discussion, workshop participants recommended several changes to the model. What follows is our interpretation and judgment of those recommendations.

- **Recommendation #1: Change the model from static to dynamic.** It is not completely clear what exactly is meant by "dynamic" in this recommendation. However, mention was made of the need for a representation of a sequence of events in the model. It is my belief, based on inferences, that workshop participants see the need for a process model of CT. In other words, they would like a CT model to describe the process of CT.

  In our view, the component of the model that needs to be made dynamic are the CT skills, depicted in Figure 1 as a "state." A psychological state should not be represented by skills because skills are merely one of the observable, and hopefully measurable, outcomes of a state. Hence, they cannot represent the state itself, only its byproducts. We know people have skills when they demonstrate they can do something and when those actions are influenced by training. Hence, inclusion of skills that represent the outcome of a state is a reasonable component to include in a nascent model. Skills are not the same as abilities, which are theoretically individual difference variables that are typically hypothesized to be heavily influenced by heredity. Logically, what is needed to describe the state is the engine that drives CT.

  Unfortunately, none of the "engines" that were offered at the workshop as possible driving forces for CT seem to fit our conception. For example, naturalistic decision making or recognition-primed decision making (RPDM) is a nonanalytic process that we believe runs parallel to CT. Even if one provides a meta-cognitive overlay on

RPDM, the basic element is recognitional and nonanalytic, is performed rapidly, and may well be algorithmic. The latter feature runs counter to the situational elements that we propose initiate CT episodes. At this point, the cognitive elements that drive CT have not been identified.

- **Recommendation #2. The model should include a condition that initiates a CT episode**. As was true for Recommendation #1, we basically agree with this second bit of advice. We are currently considering a number of theoretical conceptions that would serve to initiate CT. For example, a CT episode may be entirely started by the situation and/or stimulus. However, there must also be some cognitive element that recognizes that situation or stimulus, interprets it, and at the very least, sends a message to start the CT process. The question becomes whether initiation of CT is always a conscious decision point. It seems that there are times when people make a conscious decision to engage in deep thinking. Most of the time, however, the phenomenological experience is one of being "pulled" into the state by some external stimulus. It may be possible to solve this issue by inserting a model element between the situation and the state that signifies a perception of the situation.

- **Recommendation #3: Connect the unpleasant consequences element to the stop criteria.** In other words, when the consequences get too unpleasant, perhaps after reaching some threshold, people tend to disengage CT. A dynamic process model of the CT state may have implications for how the negative affective consequences work with the stop criteria. Other than acknowledging the relationship between the negative consequences and maintenance of CT, clarification of the relationship will have to wait for further development of the process model.

  A related recommendation was that some workshop participants disagreed that CT has negative experiential consequences. Individuals reported enjoying CT and could maintain the state for long periods of time. Hence, there may well be differences among individuals in their affective experiences of CT. Also, some participants wanted to change the predisposing attitude of "resistant to anxiety" to "tolerance for ambiguity." This recommendation was made because some individuals reported that they never experience anxiety when they are in a CT state. Hence, they preferred to express their experience as a tolerance for ambiguity.

- **Recommendation #4. Include inhibiting mechanisms that are culturally based.** A lengthy discussion at the workshop centered on how the military discourages CT because of the culture of action and decision making. A related issue was the need to carefully express oneself when you're critically thinking so as not to offend others by appearing to be too critical, questioning, or mistrustful. The ramifications of employing CT in the context of social interactions was not considered in our model development. However, it may well be possible to capture some of the effects of cultural and social situations by testing them as moderating variables in the model.

A THREE-PART THEORY OF CRITICAL THINKING: DIALOGUE, MENTAL MODELS, AND RELIABILITY

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SHOULD THE ARMY BE INTERESTED IN CRITICAL THINKING[1]?

Is critical thinking important? And if so, why? A small set of themes appears over and over in the prefaces and introductions of the dozens of critical thinking textbooks that are in print. Claims fall into three groups: *problem difficulty*, including increasing complexity of problems, changing nature of problems, and information overload; *decentralized social and organizational structure*, including increasing responsibility and need for initiative, increasing participation in teams with diverse membership, and increasing need for independent thinking; *high stakes*, including important public policy issues and personal decisions in an increasingly competitive career environment.

Do conditions for the use of critical thinking apply in the Army? The answer certainly appears to be yes. There is a growing interest in critical thinking among Army instructors and researchers, which seems warranted by the complexity and changing character of military planning and operations; decentralization of the organizational structure (e.g., the demands of leadership, coordination, and initiative within every echelon); and high stakes personally, organizationally, and for the nation as a whole. In addition, the direction of change in the Army promises to make critical thinking even more important. These changes include the growing complexity of military tasks, the rapid evolution of technology and missions, the flood of information unleashed by the new technology, increasing diversity of military organizations, and the growing interest in tactics that rely on initiative by local commanders.

A good case can be made that critical thinking is an important Army battlefield skill, and that its importance is likely to increase. But it is important to get beyond the rhetorical compatibility of claims for critical thinking and Army needs—and to evaluate the prospects of a match at a deeper and more detailed level. To dramatize the need for clarification and coherence, let us play devil's advocate. The current state of critical thinking research and instruction leaves unanswered some important questions about the application of critical thinking to the Army tactical battlefield domain:

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[1] This research was funded by Contract No. DASW01-00-C-3010 with the Army Research Institute, Fort Leavenworth Field Unit. Thanks to Dr. Sharon Riedel for her help throughout this project.

1. Is critical thinking consistent with tactical battlefield constraints?
    - Will critical thinking on the battlefield take too much time? Would that time be put to better use gaining a jump on the enemy?
    - Will critical thinking result in a loss of the confidence necessary for decisive leadership and action? Will it undermine the "will to fight"?
2. Is critical thinking consistent with other battlefield skills?
    - Will critical thinking skills trump experience or leadership qualities on the battlefield, which might in fact lead to better decisions?
    - Will critical thinking be too "critical"? Will it stifle innovation or the development of new tactics and techniques?
3. Is critical thinking appropriate for military organizational structure?
    - Will critical thinking encourage inappropriate initiative? Will it disrupt the chain of command and degrade coordination and synchronization on the battlefield? Put another way, is the Army too centralized and hierarchical for critical thinking to flourish?
    - Will critical thinking hinder the development of trust within diverse, multi-national operations because it is "Western, masculine, individualistic, adversarial, and coldly rational" (Atkinson, 1998: p.121).
4. Will critical thinking fit into Army training?
    - Are there "right answers" in critical thinking? If so, isn't this just a new phrase for teaching doctrine and tactics, which we already do? If not, what good are skills that can't be evaluated? How can we know they will improve performance?
    - Will critical thinking instruction consume too much training time? How will we persuade instructors to provide that time? Does critical thinking require technical training in logic or decision theory? Does it require stand-alone courses? How will we persuade students to devote their time to the study of critical thinking?

This article can only scratch the surface in trying to respond to these challenges. It is a very brief abridgment of Cohen, Salas, and Riedel (2001), which provides more depth and detail, but is still only a start. The research had two main goals: first, to draw a map that links disparate regions of the critical thinking field, and second, to use the map to navigate toward a more insightful theory of critical thinking, which will support the development of more effective methods for improving it in Army battlefield command teams.

THREE COMPONENTS OF CRITICAL THINKING

The essence of our theory is that critical thinking skill is exemplified by *asking questions about alternative possibilities in order to achieve some objective.* Asking and answering questions is a skill of *dialogue*. Alternative possibilities are represented by *mental models*. A process of questioning mental models is adopted because of its *reliability* for achieving the purposes of the participants within the available time. Thus, the theory of critical thinking draws

on and synthesizes research on three separate topics: cognitive theories of reasoning according to which alternative possible situations are represented by mental models; normative models of critical discussion in which a proponent must defend a claim against an opponent or critic; and models of cognitive mechanisms and of the environment which enable us to assess the reliability of the processes by means of which we form beliefs and make choices.

Critical thinking, like an onion, has a multi-layered structure (Figure 1). Each of the three layers is associated with distinctive criteria of performance, which progress from internal to external in their focus:

1. At its innermost core critical thinking involves selective consideration of *alternative possible states of affairs*. Metrics of performance at this level involve logical, probabilistic, and explanatory coherence of mental models.
2. At the intermediate level, these models are embedded within a layer of *critical questioning* which motivates the generation and evaluation of possibilities. Such dialogues may take place within a single individual, or they may be conducted among different individuals. Critical questioning is evaluated by reference to norms for conducting the appropriate kinds of critical dialogue. Dialogue types are differentiated by the depth of probing to which a proponent must respond and the scope of the permitted responses.
3. At the outermost layer, critical thinking is a judgment about the *reliability* of a cognitive faculty, hence, the degree of *trust* that should be placed in its outputs. The critical dialogue is only one of various available cognitive or social processes that might be utilized to generate beliefs and decisions. Different processes, such as pattern recognition, may be more reliable under some conditions.

In sum, critical thinking skill is exemplified by *asking and answering critical questions about alternative possible states of affairs, to the extent that such questioning is likely to increase the reliability of the overall activity in achieving its purpose*.

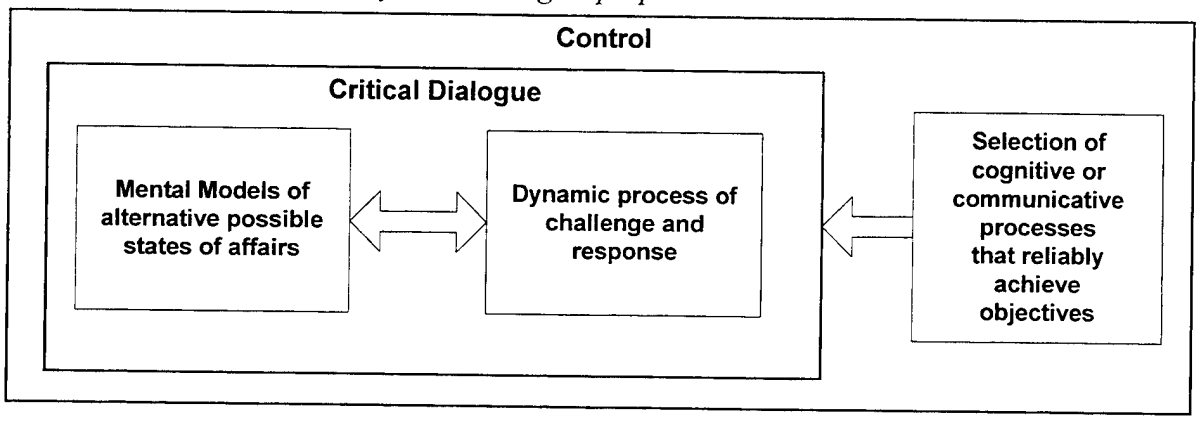

FIGURE 1: A model of critical thinking with three embedded layers: mental models, critical dialogue, and control based on reliability.

In the remainder of this article, we will very briefly discuss some of the background and rationale for this theory, and return at the end to the question of usefulness in Army battlefield decisions.

AVOIDING THE PITFALLS OF INTELLECTUALISM

Modern philosophy began (e.g., Descartes, Locke, Hume) with the notion that we have a duty to carefully *decide* whether to accept or reject our beliefs, and a duty to base those decisions upon good *evidence*. At the beginning, philosophers thought evidence was good only if it rendered a conclusion absolutely certain. Now, philosophers acknowledge uncertainty, and good evidence only needs to provide sufficient justification (whatever that is). But even so, a consistent underlying point of view has persisted and has had an enormous influence on the critical thinking movement. Even if our beliefs are *true*, unless we accepted them on the basis of what we explicitly take to be good evidence, we are correct only by a lucky accident (P. Klein, 2000).

EXAMPLE

Suppose MAJ Jones correctly believes that there is an enemy T-62 tank in the vicinity. Suppose that she believes it because she saw the tank and is in fact highly accurate in recognizing types of tanks. MAJ Jones, however, does not believe that she is sufficiently skilled to identify a T-62. Does MAJ Jones *know* that the tank is a T-62 under either of these circumstances? The intellectualist viewpoint would say no. Even though she accepts the belief based on good evidence, she does not *take* the evidence to be good. Thus, she was right about the tank by accident.

From this point of view, the purpose of critical thinking is to ensure that we have explicit reflective knowledge of all our first-level beliefs, our reasons for accepting them, and the criteria that determine whether the reasons are sufficient. Sosa (1991, p. 195) dubbed this view the "intellectualist model of justification." But is this the best view of what critical thinking is all about?

Siegel (1997) falls well within the intellectualist tradition when he says that

> ...being a critical thinker requires basing one's beliefs and actions on reasons... the beliefs and actions of the critical thinker, at least ideally, are *justified* by reasons for them which she has properly evaluated (p.14; italics in original).

This view appears everywhere in the critical thinking literature, to the point where it seems to be nothing more than simple common sense. Not surprisingly, the notion of argument (i.e., reasons for conclusions) is central in textbooks and theoretical discussions of critical thinking. Unfortunately, if applied universally and consistently as Siegel (1997: p. 16) says it should be, the demand for argument raises the danger of an infinite regress (Dancy & Sosa, 1992: p. 209-212). If reasons are required for every belief, then reasons must be provided to justify the

reasons, to justify the reasons of those reasons, and so on. Critical thinking may never come to an end. There are only three ways to respond to this problem within the philosophical tradition: The list of reasons is infinite, it circles back on itself, or it stops. If it stops, the point at which it stops may be arbitrary or non-arbitrary.

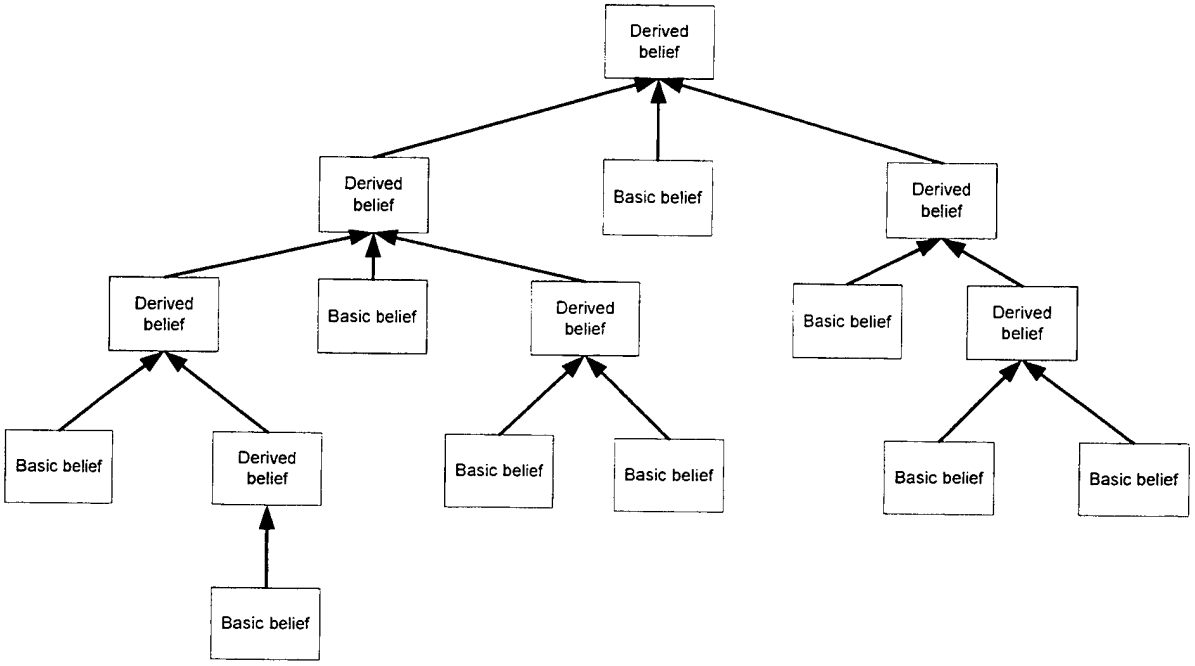

FIGURE 2: Foundationalist paradigm for acceptability of beliefs: a pyramid. Arrows represent arguments in which conclusions are inferred from reasons. Every chain of argument must be traceable back to basic beliefs, which are anchored in experience or logical intuition (shaded boxes).

If the list of reasons continues down infinitely without ever reaching bottom, conclusions can never be justified. The result is *skepticism* about the possibility of knowing anything (e.g., Ungar, 1974; Foley, 1990). A variant of skepticism is that the list of reasons ends with arbitrary assumptions that provide the basis for the other beliefs. This is the *relativist* position, that beliefs are not justified absolutely, but only relative to the framework of assumptions that happens to be accepted in a domain or culture, or even by a specific individual in a specific context. But it is hard to make a case for the usefulness of critical thinking if there are no intersubjective standards of reasoning.

A second possibility is that the chain of reasons eventually circles back on itself. For example, continuing down the chain of reasons, we would eventually arrive again at the conclusion. Siegel, like many critical thinking theorists and informal logicians, rejects the idea that a chain of arguments can legitimately circle back on itself. As he sees it (Siegel, 1997: p. 71), such an argument commits the fallacy of *begging the question*, in which the reasons for a conclusion turn out to contain the conclusion itself. In other words, the reason for accepting *p* is,

ultimately, *p* itself. Siegel (along with most other theorists in critical thinking and informal logic) is therefore committed to the third and most ambitious possibility, that the list of reasons must come to rest on solid ground, with beliefs that do not themselves require reasons and which can serve as foundations for other beliefs (Figure 2). These beliefs must be distinguished by some intrinsic cognitively accessible feature that lends them a higher level of certainty, such as their origins in perception or logic. That view is called *foundationalism* (Chisholm, 1977; Pollock & Cruz, 1999).

COHERENCE

Unfortunately, foundationalists have been unable to successfully define a convincing class of basic beliefs for which arguments are unnecessary. Virtually every belief depends in some way on other beliefs for its justification. For that reason and others, many philosophers urge consideration of a more sophisticated variant of the "circular reasoning" option called *coherentism* (Thagard, 2000; BonJour, 1985; Lehrer, 2000; Harman, 1986; Quine & Ullian, 1970; Everitt & Fisher, 1995). Coherentists accept that a chain of arguments for a conclusion will, if pursued long enough, arrive back at the conclusion itself, just as a chain of dictionary definitions will eventually arrive back at the original word. An explanatory hypothesis draws support from the observations that it explains, but also, the veracity of the observations is supported by the existence of a good explanation. In short, the premises in an argument are not "basic" in any deep sense that differentiates them from the conclusion. "Arguments" might run in either direction.

EXAMPLE

Suppose MAJ Smith believes that she saw a tank. Since a tank is an easily recognized object and visibility conditions are excellent, this is a good candidate for a basic belief. But it can be undermined if it turns out to clash with other beliefs which on the face of it seem less secure. Suppose MAJ Smith learns that the enemy has deployed dummy tanks in the region, or remembers that the area where she "saw" the tank is shown as a swamp on the map. These non-basic beliefs may trump her confidence in the perceptual judgment. Alternatively, the perceptual judgment might lead MAJ Smith to question the map or the reports of dummy tanks. MAJ Smith must determine which overall set of beliefs is most plausible, including beliefs about the presence of the tank, the accuracy of the map, the reliability of the reports about dummy tanks, and the reliability of his own perceptual judgment. In other words, MAJ Smith must evaluate the plausibility of alternative mental models. The decision whether there is a tank will depend on general beliefs about the accuracy of maps, intel reports, and perceptual experiences, which in turn depend in part on the past performance of similar maps, reports, and perceptions. That is, the selection of a plausible mental model will depend on its coherence with a larger body of beliefs, each of which is justified with respect to the others by the same set of coherence relationships.

Reasoning may be circular if carried on long enough, but coherentists deny that *justification* is circular because they reject the foundationalist equation of justification with reasoning. Justification is not directly transferred from one belief to another by a linear series of *arguments* (Day, 1989). From the coherentist perspective, it is the *system* of beliefs that is the target of justification, not the individual beliefs within it (Figure 3). A system of beliefs is coherent when its members are tightly interconnected by logical, conceptual, explanatory, or other such relationships. Every belief contributes some support to every other belief and in turn draws support from every other belief, just as each stone in an arch depends on the other stones. Arguments bear on justification *indirectly*, by exposing inferential relationships that contribute to the coherence of the system of beliefs as a whole. An individual belief is justified indirectly by having a place in such a coherent system of beliefs. Even perceptual beliefs, which were not acquired by inference from other beliefs, are justified because reasons *could* be given, e.g., by citing the reliability of visual processes under good conditions of visibility. Arguments are essential tools, since they may be used to show that a target belief coheres with other beliefs that have already been accepted. But clearly, arguments for individual beliefs have a much diminished role in settling questions of justification.

We have seen that a central problem of critical thinking is how to know when to *stop* demanding reasons for a belief. Some possible answers are:

- Skepticism: Never—justification cannot be completed.
- Relativism: At assumptions that cannot themselves be justified.
- Foundationalism: At a rock-bottom set of beliefs, based on sense perception or logic, that do not require justification in terms of other beliefs.
- Coherentism: At any already accepted members of a coherent system of beliefs.

None of these positions is altogether satisfactory. On the one hand, as we mentioned, foundationalism fails because all beliefs depend on other beliefs. A second problem with foundationalism is that it fails to explain how to choose between plausible arguments that lead to conflicting conclusions. (This is also a problem with informal logic, as discussed in Cohen, Salas, & Riedel, 2001.) On the other hand, coherentism has the opposite problems: First, some beliefs do in fact receive priority over others, even if they are not known with certainty; examples include observation reports about nearby objects in plain sight. But how can this priority be explained if every belief is justified in the same way, by its place within the same system of beliefs? Second, coherentism provides an account of how conflicting arguments are resolved, via the evaluation of alternative systems of belief. But even for moderately sized belief systems, the combinatorics of inference far exceed human cognitive capabilities (Cherniak, 1986).

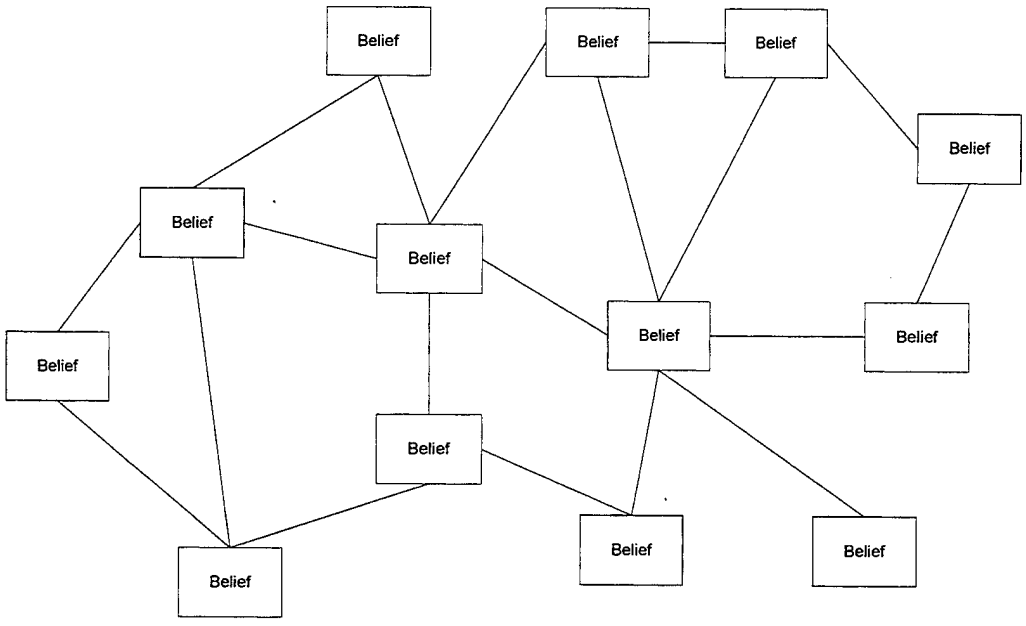

FIGURE 3: Coherentist paradigm for acceptability of beliefs: a network. The system of beliefs is justified as a whole by the inferential links among its components and its overall simplicity and comprehensiveness. Beliefs are not classified into types with different epistemological status, such as basic or not basic.

There are two kinds of responses to problems with pure coherentism, one of which makes intellectualism worse, while the other makes a dramatic break with it. The intellectualist "solution" (BonJour, 1985; Lehrer, 2000; Harman, 1973) requires a higher degree of reflective self-awareness, stipulating that the system of beliefs be evaluated in terms of coherence with second-tier beliefs about the origins and reliability of all its first-order beliefs. Thus, the priority of perceptually based beliefs is a consequence of the coherence of meta-beliefs about how reliable perception is under relevant conditions. This requirement constitutes an admission that pure coherence is insufficient to support the justification of beliefs. Specific *kinds* of beliefs (i.e., second-order beliefs about reliability) must be part of the mix. However, the demand for continuous reflective awareness exceeds human capabilities. It also threatens another kind of vicious regress, involving beliefs about beliefs, beliefs about those beliefs, and so on, unless it reverts to a form of foundationalism in which beliefs about reliability are the unquestioned foundations in need of no further arguments (Sosa, 1991, pp. 205-207).

RELIABILITY

The more appealing solution is to accept that some of the factors justifying belief acceptance may not be cognitively accessible. First, perceptual systems may reliably anchor a system of beliefs in reality even if the subject has no explicit reflective awareness of their reliability. Second, coherence may be established by relatively automatic processes of spreading activation across a network of beliefs, rather than as a result of deliberate reasoning (Thagard, 2000; Cohen, Thompson, Shastri, Salas, Freeman, Adelman, 2000b). The mutual influence of beliefs will depend on the distance that activation must travel in the network. The role of deliberate critical thought, on the other hand, is more limited: It will selectively activate and evaluate modular *subsets* of beliefs, i.e., mental models (Kornblith, 1989; Cohen, Thompson, Shastri, Salas, Freeman, Adelman, 2000a). These responses imply that a belief, whether perceptual or inferential, may constitute genuine knowledge even though the cognizer is unable to articulate reasons for holding it. This idea is called *externalism.* (The idea that our evidence for beliefs must be conscious or readily made conscious is called *internalism*, and is shared by both foundationalism and coherentism.)

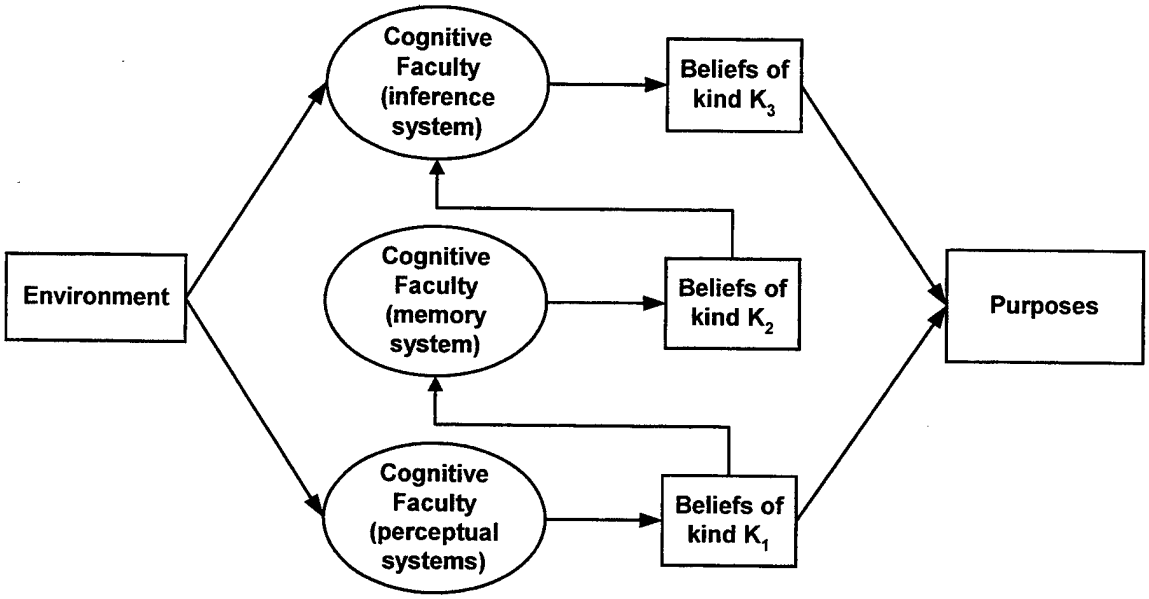

FIGURE 4: Reliabilist paradigm for acceptability of beliefs: a series of input/output processes. Beliefs are justified to the extent that they are produced or sustained by processes that reliably achieve the goal of accepting true beliefs and avoiding false beliefs under relevant environmental conditions. In the version shown here, inputs to perceptual faculties come from the environment, while inputs to memory and inferential faculties include the outputs of other belief-generation processes.

Externalism has attracted considerable recent interest from philosophers (e.g., Goldman, 1992, 1986; Dretske, 1983; Nozick, 1981; Sosa, 1991; Plantinga, 1993). According to one version of externalism, called reliabilism (Nozick, 1981), a belief is justified if it is generated or sustained by a method that "tracks" the truth, i.e., tends to produce the belief that *p* if and only if *p* is true. According to another variant of reliabilism (Goldman, 1992, 1986), a belief is justified if it is generated or sustained by cognitive processes that reliably generate truths and avoid falsehoods under the relevant conditions. Beliefs of different kinds are more or less justified depending on the processes and mechanisms that produced them and the specific conditions under which the processes were operating (Figure 4).

Externalism does not insist that a person have cognitive access to reasons for a belief, that a person have second-order beliefs about the reliability of first-order beliefs, or even that beliefs are always under voluntary control. A person is deemed expert or non-expert based on performance and results: the actual accuracy of her judgments under various conditions. Externalism accounts for our willingness to attribute knowledge to people even when they cannot accurately articulate the reasons for their judgments (Sternberg & Horvath, 1999; Berry & Dienes, 1993; Nisbett & Wilson, 1977). There is evidence that experts can become highly proficient in recognitional skills in which they are less able than novices to describe their own

thought processes. For example, expert physicians are sometimes not able to retrieve the explanation supporting a diagnosis (Patel, Arocha, & Kaufman, 1999, p. 82). Externalism allows evaluation of a belief in terms of the objective effectiveness of strategies in the external environment, relatively automatic processes (such as perception, pattern recognition, and constraint satisfaction in connectionist networks), and features of cognitive mechanisms (such as processing capacity and the structure of knowledge in long-term memory). It thus promises more fundamental integration with concerns of cognitive psychology.

Objections to reliabilism have stressed several points: First, there is the *coherence* problem. Judgments about reliability must be part of a network of beliefs that is evaluated with respect to its coherence. Thus, there is no escaping the kind of "circularity" emphasized by coherence theories (Sosa, 1991). Coherence theories stress the coherence of reliability judgments, while externalist theories stress the reliability of judgments based on coherence. But which is primary?

Second, there is the *generality* problem. The reliability of a cognitive faculty might be thought of as its ratio of successes to failures under specified circumstances. But then, reliability depends on how generally or specifically the circumstances are specified (Conee & Feldman, 2000). If they are specified too generally, reliability is not very informative. For example, visually formed beliefs seem to be generally reliable; but visual pattern recognition processes that identify a nearby object as a tank in good conditions are much more reliable than the average visually formed belief. But should we also include the condition that dummy tanks exist in the area? If so, that same process is less reliable than the average visually formed belief. If we describe the actual present conditions with maximal specificity, then reliability reduces to truth or falsity of the belief in the particular case. But justification should not entail absolute certainty; it should be possible to have a justified belief that is false or an unjustified belief that is true. How then is the appropriate level of generality chosen?

The third and final problem concerns *fairness* in evaluation. Recall MAJ Jones, who has a highly reliable faculty for quickly recognizing different types of tanks as a result of long training and experience. But MAJ Jones does not realize how reliable her judgment is and indeed believes it to be unreliable. MAJ Jones would seem to be unjustified in accepting her own beliefs about tanks, even thought they are reliable (Bonjour, 1985). Given her beliefs about her own unreliability, she would be right to double check the tank identifications before accepting them. Conversely, recall MAJ Smith. Her faculty for recognizing the presence of a tank is generally reliable, but is unreliable under special circumstances (such as when there are dummy tanks in the area). But if MAJ Smith had no way of knowing that dummy tanks were in the area, or indeed had reason to believe there were none, wouldn't her tank identifications be justified even though they were unreliable? Both of these points have been taken to suggest that internalist

intuitions based on fairness, both in holding people responsible for errors and giving them credit for successes, are not accounted for by externalism.

Solution of these problems, and a reconciliation of reliabilism and coherentism, requires the recognition of two distinct points of view: the person whose knowledge is being assessed (call her the proponent P) and the person who is assessing that knowledge (call her the judge J). Judgments of reliability of P's beliefs are made by the assessor J. The assessor's purpose is quite straightforward. J would like to be able to use P's opinions as a source of information in a particular range of circumstances, but in order to do so must assess the extent to which P's beliefs can be trusted in those circumstances. J asks, for example: Can I infer from the fact that MAJ Jones believes this tank is a T-62 to the conclusion that it is a T-62? Can I infer from the fact that MAJ Smith believes there is a tank in the vicinity to the conclusion that there is a tank in the vicinity? J would like to infer from P's having a certain belief, that the belief is true and can be justifiably endorsed and adopted by J herself (Brandom, 2000, p. 120).

Distinguishing these two points of view enables us to resolve the coherence problem. From the point of view of the assessor J, judgments of the reliability of P must be arrived at just as other judgments are, by reference to their coherence with J's other beliefs and their fit to J's perceptual experiences. As Brandom puts it, concern with reliability is *external* only "because assessments of reliability (and hence of knowledge) can turn on considerations external to the reasons possessed by the candidate knower [P] himself." But assessments of reliability are *not* external to the reasons possessed by the assessor J. They inevitably occur within J's own system of beliefs, and coherence with those beliefs is a major determinant of J's conclusions regarding the reliability of P. Dual-perspective reliabilism takes seriously the coherentist conclusion: Second-order beliefs about reliability are required in order to anchor a coherent system of beliefs in reality. But it rejects the requirement that those second-order beliefs be part of the same system that is being evaluated.

Similarly, the generality problem arises only when reliability assessments are thought of as lacking a point of view, hence, as independent of both reasons and purposes. Since reliability is assessed from J's perspective, the scope of reliability assessments will depend on J's beliefs and purposes. In particular, reliability assessments will depend on (a) what J knows about the situation, (b) what J knows about P, and (c) the range of situations in which J might want to trust P as a source of information. If J is concerned with the trustworthiness of MAJ Smith's perceptual recognition of a tank and is aware of the presence of dummy tanks in the area, J will not regard MAJ Smith's judgment as reliable evidence for the presence of a tank. But if J trusts MAJ Smith generally, if the situations where dummy tanks are present constitute a small minority, and if J is not aware of the presence of dummy tanks in the area, then J will justifiably conclude that MAJ Smith's tank report is reliable.

The fairness problem is in part a matter of divergent purposes between internalist and externalist points of view. According to internalism, the purpose of critical thinking is to fulfill an intellectual duty, to carry out one's intellectual responsibilities in a blameless way. Thus, it is unfair to blame a critical thinker for disregarding relevant evidence if that information was not cognitively accessible (It is also unfair to credit her for ignoring evidence that was cognitive accessible, just because that information turned out to be inaccurate). But externalism shifts the purpose of critical thinking: It emphasizes the bottom line: accepting significant true beliefs and rejecting significant false ones. Because of this shift, there is no longer an issue of "fairness" in allocating praise and blame. Nonetheless, internalist intuitions about fairness can be captured in an externalist account by considering point of view. The candidate knower may assess the reliability of her own beliefs, adopting the perspectives both of assessor J and of subject of assessment P. Intuitions about fairness tend to correspond to the point of view of the candidate knower when evaluating the reliability of her own judgments. From MAJ Smith's own point of view, her recognition of a tank is reliable because she believes that dummy tanks are not likely. And since MAJ Jones thought her tank identifications were unreliable, she could not be blamed for seeking further verification before accepting her perceptual judgments. Both MAJ Smith and MAJ Jones made reasonable decisions based on the reliability assessments they made about their own judgments. J reached different conclusions simply because J had more information than they did.

But if the two perspectives can be combined within the same person, how can they remain distinct? Wouldn't reliability judgments be identical to the judgments arrived at by the first-order process? In other words, if a reasoning process inferred a probability of .8 confidence in a conclusion, wouldn't the assessment of the reliability of that belief also have to be .8, if it is done by the same person? The answer is no. The reality of the different viewpoints is confirmed in an experimental study by Leddo and Govedich (1986), in which different points of view were induced by assigning different roles to participants. Participants were asked to estimate the chance of success of a battle plan. Participants could be assigned the role of planners or of implementers. When participants performed as implementers, they adopted an internalist point of view. They tended to estimate the chance of success by considering the possible *reasons* the plan might fail. This exercise helped them anticipate and prepare for potential problems during the execution of the plan. But since the implementers inevitably overlooked some possibilities, they overestimated overall chance of success. When participants performed as plan developers, on the other hand, they adopted an externalist point of view. They tended to estimate chance of success statistically, by reference to the past frequency of success in plans of a similar kind, not by enumerating failure scenarios. As a result, planners were less overconfident.

The two points of view are distinct even when they are both embodied in the same individual. Critical thinking occurs *internally* by challenging a thesis or plan and making

adjustments in response to problems that are found. In the internalist sense, critical thinking is an intrinsic part of reasoning. But critical thinking occurs *externally* by stepping back and questioning the reliability of the process as a whole under relevant conditions, in order to select the appropriate process, regulate its use of resources, and determine when confidence in the conclusion is high enough to stop. Since this kind of evaluation is done "from the outside," the process being evaluated may, but need not itself involve reasoning; instead it might concern the accuracy of a perception, recall, or recognition. The two viewpoints draw on different kinds of information and involve different attitudes. They correspond to distinct but equally important levels of critical thinking.

RELIABILITY AND COHERENCE IN CRITICAL THINKING

Critical thinking research and teaching has paid scant attention to non-foundationalist viewpoints (Freeman, 2000). This is the reason that the concept of *argument* (with individual beliefs as conclusions) has occupied center stage. Non-foundationalist approaches such as coherentism and reliabilism, shift the emphasis away from deliberative arguments about individual beliefs. Coherentism accounts well for the mutual adjustment of beliefs to one another in networks, but not for the special role of perceptual inputs or for computational limitations. Reliabilism accounts for beliefs in terms of the specific cognitive faculties that generate or sustain them, including both perceptual and inferential systems as they operate in real environments.

The three-part model of critical thinking (Figure 1) integrates insights from coherentist and reliabilist theories of justification. The version of reliabilism depicted in Figure 4 has a foundationalist flavor because reasoning builds on a distinct, privileged class of beliefs generated by perception. By contrast, Figure 5 is a reliabilist framework that incorporates both coherentism and critical thinking. No beliefs are immune to revision based on incoherence with other beliefs. Perceptual systems produce *experiences* rather than beliefs, and these experiences are causal inputs to belief generating faculties. In other words, Figure 5 rejects the foundationalist assumption that there is a privileged class of beliefs that is immune to reasoning. On the other hand, it acknowledges that perceptual experience is an essential input to a coherence-based belief system (c.f., Haack, 1993; Thagard, 2000). The role of beliefs that are closely related to perceptual experiences is explained by appeal to their reliability, but it is not necessary for the *candidate knower* herself to have reflective second-order beliefs about her first-order beliefs, as coherence theories require.

The three-part model of critical thinking forms the top tier of Figure 5, consisting of critical dialogue about mental models to achieve purposes under specific environmental conditions. Although critical thinking is reflective, it interacts with the more automatic operation of the coherence system. It takes sets of beliefs from the coherence system as inputs, creates and critically evaluates mental models, and in turn feeds its conclusions back as inputs to the

coherence system. All cognitive faculties—perception, coherence-based reasoning, and critical thinking—are designed to reliably achieve particular purposes in particular environments in consort with each other. Judgments of reliability may be made from an external point of view, to determine whether another person's opinions can be trusted, or may be made internally (but still, from a hypothetical "outside" point of view) to regulate use of one's own faculties in knowledge acquisition.

We will now discuss in a bit more detail how the components of this model work together in critical thinking.

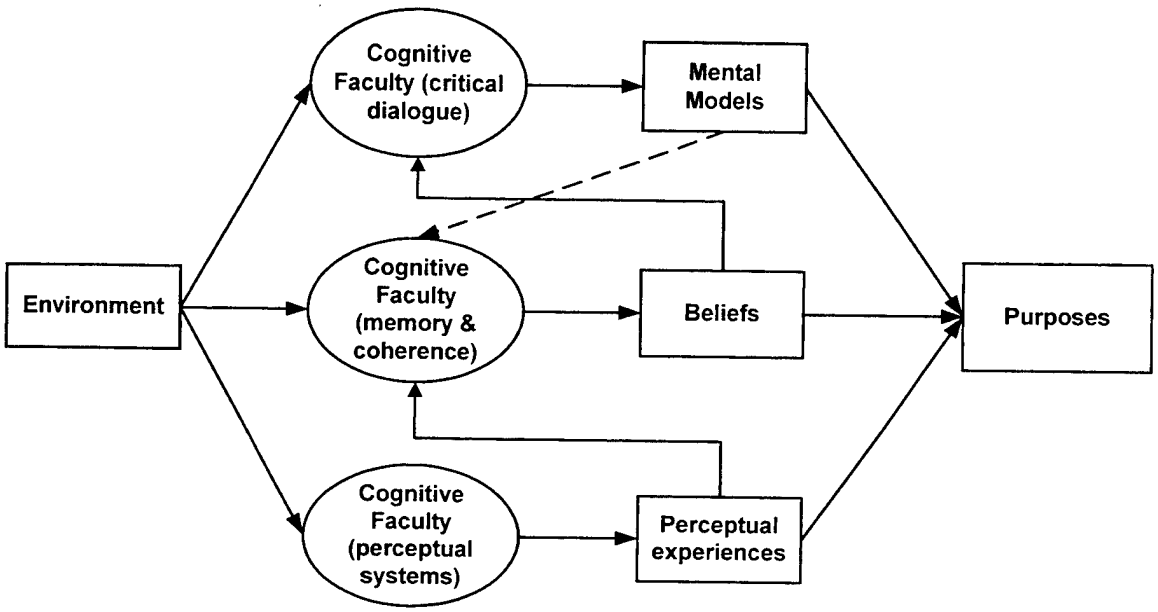

FIGURE 5: A reliabilist framework that integrates a coherence theory of reasoning with the critical thinking model in Figure 1.

MENTAL MODELS

Johnson-Laird (1983; Johnson-Laird & Byrne, 1991) cites evidence that humans reason not (or not only) in terms of syntactic formal patterns but in terms of *meaning*. Comprehending an assertion includes understanding what possible states of affairs are compatible with the assertion and which are excluded (Johnson-Laird & Byrne, 1991). *Inference* is in large part a process for comprehending multiple assertions, that is, for determining what states of affairs are consistent with several different assertions. The conclusion of an inference must be true in every surviving possibility.

The representation of a possible state of affairs is called a *mental model*. Typically, a simple statement (e.g., *the enemy will attack through the northern pass*) is compatible with many

different states of affairs (when and how they will attack), but people often use a single, representative mental model to conserve processing capacity (Johnson-Laird & Byrne, 1991, p. 170). They change the representation or expand it to include other possibilities only when forced to do so. When a sentence contains logical connectives, such as *and*, *or*, *all*, and *some*, people use knowledge of the meaning of such connectives to construct some or all of the appropriate mental models. Suppose MAJ House and MAJ Kerr are analyzing enemy intent, and MAJ House says:

> MAJ House: *The enemy will attack either through the northern pass or the southern pass.*

Neither MAJ House nor MAJ Kerr believes the enemy will attack through both passes. The *or* statement thus suggests only two possible mental models: one in which the enemy attacks in the south (and not the north), and the other in which they attack in the north (and not the south):

1	*The enemy will attack through the south*	*NOT: The enemy will attack through the north.*
2	*NOT: The enemy will attack through the south*	*The enemy will attack through the north.*

To conserve processing capacity, according to Johnson-Laird, and Byrne, people usually do not represent negations unless they are stated explicitly. So, the two cells with NOT would be left blank.

Now suppose MAJ Kerr says, "*I don't believe it will be the northern pass.*" MAJ Kerr has committed herself to mental model #1:

1	*The enemy will attack through the south.*	

MAJ House, however, is still uncertain, and wants to know the reasons for this conclusion. MAJ Kerr replies, "*Because they don't have any artillery there.*" Background knowledge of enemy doctrine suggests that the enemy will not attack without using artillery first to soften up the opposing force. Thus, only attack in the south is consistent with the absence of artillery in the north. Hence, MAJ Kerr has concluded that the enemy will attack in the north. The following mental models capture MAJ Kerr's reasoning, and also show how she intends to persuade MAJ House to accept mental model #1:

	The issue		MAJ Kerr's reason	
1	*The enemy will attack through the south.*		*NOT: The enemy has artillery in the north.*	This mental model is consistent with background knowledge.
2		*The enemy will attack through the north.*	*NOT: The enemy has artillery in the north.*	This mental model is ruled out by background knowledge of likely enemy tactics.

In this example, background knowledge ruled out mental model #2. However, Johnson-Laird and Byrne (1991) show how such conclusions can be reached by more explicit deductive reasoning with mental models. Such reasoning is typically more effortful. For example, suppose MAJ Kerr had said:

> MAJ Kerr: *If they were going to attack in the north, they would have artillery nearby. And they don't.*

Considering only the simple components of MAJ Kerr's statements, there are four logical possibilities, corresponding to different combinations of truth and falsity of attack in the north and artillery in the north. The conditional statement (*If they were going to attack in the north, they would have artillery nearby*) excludes just one of these four situations:

1	*NOT: The enemy will attack through the north.*	*NOT: The enemy has artillery in the north.*	
2	*The enemy will attack through the north.*	*NOT: The enemy has artillery in the north.*	This situation is excluded by the If__then__ statement.
3	*NOT: The enemy will attack through the north.*	*The enemy has artillery in the north.*	
4	*The enemy will attack through the north.*	*The enemy has artillery in the north.*	

(We omit the column for attack in the south for simplicity.) The other part of MAJ Kerr's argument is that the enemy does not have artillery in the north. Adding that piece of information excludes mental model #3 and mental model #4. Thus, the only surviving possibility is mental model #1, and the conclusion is that the enemy will not attack in the north.

According to mental model theory, the difficulty of an inference increases with the number of alternative possibilities that must be considered. Thus, the use of background knowledge (i.e., the automatic operation of a coherence-based network of beliefs) to eliminate at least some of the possibilities, as in our example, is much less effortful than explicit inference. Indeed, a major advantage of mental model theory over other approaches is that it can accommodate both automatic and deliberate processes in any mix. Errors in explicit inference may occur for several reasons: the number of possibilities exceeds capacity limitations of working memory (Johnson-Laird & Byrne, 1991, p. 39); there is a tendency to represent only explicit and true components of premises and thus to neglect possibilities consisting of false components; or a prior tendency to believe that the conclusion is correct causes the reasoner to cut short the exploration of alternatives. Of course, another possible cause of error is elimination of possibilities due to inaccurate background beliefs. Because of such limitations and biases, people are liable sometimes to accept a conclusion even though there is a possible state of affairs in which it is false.

DIALOGUES

The field of informal logic has lacked a unifying theory that successfully accounts for different types of arguments and the errors to which they are subject (Walton, 1998, p. 7). A promising approach, which is drawing increasing attention, is the interpretation of argument as a component of *dialogue*. As Johnson (1996) says, "an argument understood as *product*—a set of propositions with certain characteristics—cannot be properly understood except against the background of the process which produced it—the process of argumentation." Dialogue theorists attempt to describe argumentation by means of rigorous, idealized models of interactive exchanges. Such models specify the purposes of different types of dialogue, the roles that are played within the dialogue, rules for each player, and rules for determining who wins. Actual discussions can be analyzed and evaluated in terms of how closely they approximate the appropriate paradigm (Walton & Krabbe, 1995, pp. 174-177).

The pragma-dialectical theory proposed by van Eemeren and Grootendorst (1994) closely interweaves normative and descriptive elements. An ideal of critical rationality in dialogue is developed, while at the same time actual processes of argumentative discourse are studied empirically. Actual argumentative discourse is reconstructed from the perspective of the ideal of *critical discussion.* This permits the discovery of practical problems or errors experienced in argumentative discourse, and forms the basis for development of appropriate methods in education (van Eemeren, Grootendorst, & Snoeck Henkemans, 1996). The source of the norms is an ideal of actual human discourse, rather than a formal axiomatic system (as in logic or probability theory). According to Walton (1996b), "A dialogue is a goal-directed, collaborative conversational exchange, of various types, between two parties. ... fallacy is defined as an

argument or a move in argument that interferes with the goal of a dialogue of which it is supposed to be a part...."

Dialogue theory provides a deeper analysis of fallacies than the usual description in terms of surface features. For example, one fallacy is typically described as attacking the person, or *ad hominem*. A simple example of a rule of discourse emerging from dialogue theory is the following: "Parties must not prevent each other from advancing standpoints or from casting doubt on standpoints." *Ad hominem* fallacies sometimes involve violation of this rule. According to dialogue theory, when personal attacks are intended to prevent an opponent's views from being fairly considered, the violation of the rule of cooperation is what makes this an error, not surface features ("attacking the person"). Other fallacies (e.g., argument by appeal to pity, or threats of force) that described very differently from *ad hominem* appear to involve violation of the same dialogue principle and thus are the same error when considered at a deeper level. Conversely, in other contexts, impugning the character of a person may be highly appropriate, e.g., if the person's testimony must be relied on in drawing a conclusion. Understanding errors in terms of dialogue rules provides both a more nuanced and a more accurate assessment of their normative status.

Walton (1998) has studied a variety of different kinds of dialogue, which differ in their purposes and the norms by which they are conducted: e.g., deliberation, inquiry, negotiation, information seeking, and persuasion. According to dialogue theories, participants cooperate to choose the type of dialogue that is best for the purpose and context (van Eemeren & Grootendorst, 1992). Hence, they must make reflective judgments about the relative reliability of different dialogues as methods for achieving their goals. They must also reflectively monitor adherence to the norms that govern the relevant type of dialogue (Jackson, 1989; Johnson, 2000).

According to van Eemeren and Grootendorst (1992, pp. 34-37), a *critical discussion* is a dialogue type used for the resolution of a difference of opinion. Resolution is not a matter of negotiation (which is a different type of dialogue) or of simply setting the difference aside. It involves *persuading* one of the parties to retract doubt concerning the other party's position because she has been convinced by the other party's reasons, or conversely for one of the parties to relinquish her own position because it has not withstood the other party's challenges. In some dialogue models (e.g., Walton, 1998; van Eemeren and Grootendorst, 1992), there are two participants or roles: a *proponent* and an *opponent*. In other models (e.g., Rescher, 1977), there are three participants or roles: a *proponent*, an *opponent*, and a *judge*. Rules governing the possible actions of each participant are a function of the type of dialogue, the stage of the dialogue, and the previous statements of each participant.

In the *confrontation* stage of a critical discussion, a difference of opinion is acknowledged. For example, the proponent expresses a standpoint with or without reasons, and the opponent indicates disagreement or expresses doubt. The parties may also seek to clarify or

flesh out each other's positions. In the *opening* stage, which is likely to be implicit rather than explicit (van Eemeren and Grootendorst, 1992, p. 41), the parties "agree" on the type of discussion they will have and the discussion rules. Specifically, in the type of dialogue called a critical discussion, they agree that one will take the role of proponent and the other will take the role of the opponent. The proponent incurs an obligation to defend or modify her standpoint at each move, and the opponent incurs an obligation to accept or reject the proponent's assertions at each move. They agree that each assertion must support the goal of the dialogue type they have selected, e.g., to resolve the difference of opinion, and they agree not to shift dialogue types without mutual agreement. They also agree to distinguish which assertions are meant as conclusions and which are meant to be reasons for those conclusions.

The crucial stage of a critical discussion is *argumentation*, in which the proponent and opponent carry out their roles of defending and challenging a thesis, respectively. Normative models of this stage spell out the types of assertions that are permitted to each side as a function of previous assertions. The major difference between the proponent and opponent in a critical dialogue is the global burden of proof. It is up to the proponent to create a positive case for her standpoint. The opponent merely has to create doubt. (In more complex types of dialogue, the two parties may defend contrary theses, and each participant in effect plays opponent to the other.) Although the global burden of proof is static (and rests upon the proponent), as each side provides arguments or challenges, the local burden of proof switches back and forth (Rescher, 1977, p. 27). That is, whenever either side advances an argument, it stands until explicitly rebutted by the other side. In the *concluding* stage of a critical discussion, the dispute may be ended because the proponent withdraws her thesis or because the opponent withdraws her doubt.

The critical discussion (or the more general *persuasion* dialogue described by Walton, 1998) provides a promising framework for both understanding and training critical thinking. The primary reason for its usefulness is the functional similarity between rationally persuading another individual to accept or reject a position, and rationally determining for oneself whether a position is acceptable or not. The idea of a dialogue externalizes necessary functions that must take place within an individual cognizer. Thinking may be fruitfully studied as a form of internal dialogue in which a single individual takes on distinct dialectical roles (Walton, & Krabbe, 1995, p. 26). Another reason for focusing on dialogue as a model of thinking is that the functional resemblance between thought and dialogue is more than a coincidence. A variety of developmental psychologists (starting perhaps with Vygotsky) have proposed that thought first develops in each individual as internalized speech and that we learn to reflect on and evaluate our own thoughts by responding to the thoughts of others (Bogden, 2000). As noted by Rieke and Sillars (1997),

> ...research suggests that critical thinking is really a mini-debate that you carry on with yourself. What is often mistaken for private thought is more likely an

"internalized conversation" (Mead), an "internal dialogue" (Mukarovsky), or an "imagined interaction" (Gotcher and Honeycutt).

A final reason for interest in dialogue theory is more direct. Much critical thinking takes place in a team or group context, in which dialogue plays a *literal* role in decision making. The road to improved critical thinking in both an individual and a team context may lead through training in improved skills and habits for critical dialogue.

MENTAL MODELS AND DIALOGUES

The argumentation stage of a critical dialogue can be seen as a process of constructing and evaluating mental models. Dialogue theory links up with mental model theory via its concept of a *commitment store* (Hamblin, 1970; Rescher, 1977; Walton & Krabbe, 1995). According to Hamblin (p. 257), "a speaker who is obliged to maintain consistency needs to keep a store of statements representing his previous commitments, and require of each new statement he makes that it may be added without inconsistency to this store..." Walton and Krabbe (1995) distinguish two kinds of explicit commitment stores: commitments based on assertions, which the speaker is obligated to defend, and commitments by a listener based merely on concessions, which the listener is not obligated to defend.

Rules for permissible moves in the argumentation stage of a dialogue refer to the current status of these commitment stores, and specify how each move changes their contents. The listener can challenge any assertion by the speaker as long as that assertion is not in the listener's own assertion-based commitment store. If the listener challenges a commitment based on an assertion by a speaker and the speaker cannot defend it by supplying reasons, the speaker must retract it. When the listener does not immediately challenge an assertion by the speaker, the listener has conceded it, and it goes into the listener's concession-based commitment store. The listener is of course not obligated to defend her concession, but must allow the speaker to use it in argumentation at least for the time being. The listener can retract the concession at any time simply by challenging it, as long as it is still in the speaker's commitment store (otherwise, the challenge would be irrelevant). The speaker can also choose to retract an assertion of her own, but this is more difficult to do because she must also find and retract any other commitments that imply the retracted assertion (i.e., the reasons she may have given for her assertion). If there are inconsistent assertions in the speaker's commitment store, and the listener challenges them, then the speaker must retract at least one of the conflicting commitments along with the reasons that led to it.

Commitment stores are simply sets of mental models. Each mental model in the commitment store of a dialogue participant represents a state of affairs that is regarded as *possible* by that participant at that particular time. For example, in the argument about location of attack, MAJ Kerr is the proponent. She stated a thesis (that the enemy attack will be in the south) which MAJ House did not concede. MAJ House thus takes the role of opponent. In response to

MAJ House's challenge, MAJ Kerr gave a reason (lack of artillery in the north) that was intended to persuade MAJ House to exclude the competing possibility.

Now suppose MAJ House concedes that absence of artillery in the north would be a good reason to accept MAJ Kerr's conclusion, if the reason were true. (In other words, she chooses not to challenge that aspect of the argument for the time being.) But MAJ House expresses doubt about the reason itself: "*What makes you think there is no artillery in the north?*" Since MAJ House does not concede the truth of the reason, the opponent's mental models now include the following different situations:

Opponent

	The issue		**Proponent's reason**	
1	*The enemy will attack through the south*		*NOT: The enemy has artillery in the north.*	
2		*The enemy will attack through the north.*	*NOT: The enemy has artillery in the north.*	Opponent concedes that this possibility is (temporarily) excluded
3	*The enemy will attack through the south*		*The enemy has artillery in the north.*	Opponent questions reason, hence, still believes these are possible.
4		*The enemy will attack through the north.*	*The enemy has artillery in the north.*	

Notice that the opponent, MAJ House, is not committed to the negation of the reason (that there *is* artillery in the north), but only to the *possibility* that there is artillery in the north. Nor is the opponent saying that the conclusion is false. But she is saying that the possibility of artillery in the north opens up the *possibility* of attack in the north. Specifically, in mental model #4 the enemy has artillery in the north and attacks through the north. Since the proponent's conclusion is not true in all the possible situations, the opponent is not yet convinced. In order to persuade the opponent, the proponent must find some way to eliminate mental model #4. Suppose that the proponent now presents a reason to believe that the enemy has no artillery in the north:

Proponent

	Issue		Proponent's reason	Proponent's reason for the reason
1	*The enemy will attack through the south.*		*The enemy has no artillery in the north.*	*Our imagery of the northern sector is excellent and shows no artillery in the north.*

This time the opponent, MAJ House, concedes the truth of MAJ Kerr's reason (the imagery is good and showed no artillery in the north). But now she wishes to go back and challenge something that she had temporarily conceded: MAJ Kerr's claim that absence of artillery is in fact a good reason under these circumstances for expecting no attack in the north. In particular, MAJ House points out, "*Don't we have reports that the enemy has developed longer-range artillery?*" This move is the opposite of the previous one. MAJ House accepts the truth of the reason (no artillery in the north) but has introduced a consideration intended to neutralize or cancel it out as evidence for the conclusion (no attack in the north). The absence of artillery in the north, in conjunction with the fact that the enemy has developed longer range artillery is *not* evidence for the conclusion (since the enemy could use artillery located at a longer distance). We call such an objection a *defeater*. The opponent's mental models are now the following:

Opponent

	Issue		Proponent's reason	Proponent's reason for the reason	Opponent's defeater
1	*The enemy will attack through the south.*		*NOT: The enemy has artillery in the north.*	*Our imagery of the northern sector is excellent and shows no artillery in the north.*	*The enemy has developed long range artillery.*
2		*The enemy will attack through the north.*	*NOT: The enemy has artillery in the north.*	*Our imagery of the northern sector is excellent and shows no artillery in the north.*	*The enemy has developed long range artillery.*
			...	...	

The three dots indicate that the opponent has merely conceded the imagery evidence and thus the absence of artillery in the north, but is not committed to defending them. She is at liberty to challenge them again later. We have used Johnson-Laird's (1983) convention for representing implicit mental models as a handy way to represent concessions in a commitment store.

The opponent's challenge to MAJ Kerr's argument introduces the very important topic of *defeasibility*, and shows how dialogue theory and mental models in conjunction help clarify some key aspects of reasoning about uncertainty. Informal logicians, psychologists, philosophers, and artificial intelligence researchers generally agree that non-deductive inferential conclusions are subject to defeat by new information, i.e., such inferences are *defeasible*. As we have seen, a defeater (e.g., the development of longer range artillery) may undermine an inference without providing evidence for the opposite conclusion. Notice in addition that the opponent does not even deny that the original evidence (the absence of artillery in the north) supported the proponent's conclusion (no attack in the north). The opponent merely points out that while no artillery generally indicates no attack, there are special circumstances in this situation that must be taken into account. The further bit of information about longer range artillery *neutralizes* the support given by the proponent's evidence for the proponent's conclusion in this context. At this stage of the dialogue, MAJ Kerr's argument is defeated and no

conclusion about location of attack can be drawn. Thus, she may have to retract her conclusion about attack in the south.

Defeasibility, however, is an open-ended aspect of reasoning about the real world. Thus, MAJ Kerr may answer MAJ House's challenge by defeating the defeater. For example, MAJ Kerr replies: "*That may well be, but I don't recall any indications that they've deployed the new systems yet.*" If the enemy has not deployed the new artillery, then mere development of the technology is irrelevant. The original argument based on lack of artillery in the north regains its former force. The proponent's commitment store still has only one explicit mental model:

Proponent

	Issue		**Proponent's reason**	**Proponent's reason for the reason**	**Opponent's defeater**	**Proponent's defeater of the defeater**
1	*The enemy will attack through the south.*		*NOT: The enemy has artillery in the north.*	*Our imagery of the northern sector is excellent and shows no artillery in the north.*	*The enemy has developed long range artillery.*	*The enemy has not deployed the new artillery.*
					...	

The three dots show that MAJ Kerr has conceded the development of longer range artillery but may choose to make alternative possibilities explicit later. In this mental model, it is clear that the three claims in combination—lack of artillery in the north, and possession of longer range artillery that has not been deployed—do provide evidence against attack in the north. Thus, only one possibility survives, mental model #1, in which the enemy attacks in the south. MAJ Kerr's original conclusion has been vindicated—unless of course the opponent comes up with another challenge, to which MAJ Kerr has no response.

Defeasibility is pervasive in everyday reasoning but is not handled well within either formal or informal logical systems. Logicians tend to deal with defeasibility by tinkering with the premises or inference rules of a reasoning system. For example, they might add the falsity of the defeater to the premises in the argument—e.g., artillery location is an indicator of location of attack only if longer range artillery has not been developed and deployed. The problem with this tactic, aside from computational complexity, is that it blocks reasoning with incomplete information. The falsity of all possible defeaters would have to be positively determined whenever artillery was used as an indicator of location of attack. But in many circumstances, this

is either not possible or not worth the time. As the conversation between MAJ Kerr and MAJ House continues, more exceptions and exceptions to exceptions may be brought forward. Each new addition of clauses to the premises would ratchet up the demand for information before the inference can be regarded as valid. As a result, the decision maker might never be able to reach a conclusion at all. A partial solution is to add special default inference rules, so that the conclusion follows in the absence of positive evidence that the defeaters are true (e.g., Reiter, 1980). Again, however, this introduces extreme computational complexity. Another problem is that the list of potential defeaters is indefinitely long, and advance specification of all defeaters in special default rules may be impossible even in principle. The set of defeaters for the inference from an effect to a cause, for example, must include *all* the other possible causes. Even more importantly, the logical approaches provide neither guidance nor flexibility in determining how long the process of generating defeaters and collecting information about them should go on. Proficient decision makers are able to adapt the reasoning process to specific circumstances, to act decisively on a subset of the relevant information in situations where that is necessary, and to demand more thinking and more information where that is called for.

The problem of defeasibility invites a constructive solution involving a synthesis of mental model theory, dialogue theory, and reliability. Defeasibility always involves an initially incomplete set of mental models. Put the other way, it involves the discovery of possible states of affairs that were not previously considered but which are relevant to the conclusion in the current context. Thus, it lends itself to a semantic mental model-based approach that represents the alternative possibilities that are considered in reasoning (Johnson-Laird & Byrne, 1991; Johnson-Laird, Legrenzi, Girotto, Legrenzi, & Caverni, 1999). The reasoning process itself alternates steps of generating new possibilities and using background knowledge or explicit inference to evaluate their plausibility. Dialogue theory provides norms for the process of challenge and response during which mental models are elaborated and accepted or rejected. Finally, as we shall see, judgments of reliability determine what the process should be used and when the process should stop in any particular situation

As the critical dialogue progresses, new features are added to the model, either to challenge or to defend the proponent's conclusion. Thus, the model shows how argumentation expands the sharing of knowledge between dialogue participants. For an individual, critical dialogue has a function of eliciting knowledge that may not otherwise have been used in the current problem. The features elicited in critical dialogue are represented by columns in the mental model tables. Each feature is a dimension along which possible states of affairs can vary. Thus, each new feature increases the number of logically possible situations, i.e., the combinations of truth and falsity. For example, since there are six features (columns) in the final step of our example, there are actually $2 \times 2 \times 2 \times 2 \times 2 \times 2 = 64$ possible states of affairs! Clearly, it would be impossible for humans to keep that many possibilities in mind, and

fortunately it is not necessary. As the example illustrates, because of the role of background beliefs and the avoidance of explicit deductive inference, the actual number of mental modes that needs to be considered is much lower, and does not necessarily increase much at all as new dimensions are introduced. The objective of the proponent is to *reduce* the number of mental models until all the survivors contain the conclusion, and she does so by introducing new considerations that interact appropriately with background knowledge. In addition, concessions function as assumptions which reduce the range of alternatives to be considered. This example required explicit representation of only one or two of the 64 logically possible mental models at any given time.

The objective of the opponent, of course, is to increase the number of mental models, i.e., to force the proponent to consider and respond to alternative possibilities in which her conclusion is not the case. The evolution of mental models for both the proponent and opponent thus provides a vivid record of the progress of a critical dialogue, and clarifies the kinds of moves that each side should make in order to persuade the other.

RELIABILITY

A problem that is not addressed by either mental model theory or dialogue theory is the choice of a strategy that will reliably achieve *external* objectives. This gap exists because of the *internalist* character of both mental model theory and dialogue theory. According to internalist theories, criteria for assessing the acceptability of beliefs must always refer to cognitively accessible internal representations, and not external facts of which the cognizer was not aware. Dialogue theory refers to two people engaged in an overt verbal exchange. Despite this public character, dialogue theory has more kinship to internal approaches. It focuses primarily on internal conformity of a verbal exchange to the norms of a particular type of dialogue, rather than on the selection of the dialogue type and regulation of the dialogue itself in a way that is appropriate for an external task. Two features clinch its internal status: First, the norms are applied only to facts that are *known* to one or both of the participants. Second, the evaluation focuses on proximal or internal objectives associated with a particular type of dialogue, e.g., resolving a conflict of opinions, rather than on distal or external objectives, such as accomplishment of a task or mission. Because of these internal norms and proximal objectives, dialogue theory tends to describe self-enclosed games. Its internal focus is responsible for the failure of dialogue theory to adequately address three key issues: The selection of the appropriate types of dialogue, the rules for bringing a dialogue to an end, and how to determine the winner. All of these issues require judgments of external reliability.

Dialogue theory does not address the rationale for choosing a particular dialogue type on a particular occasion, i.e., how different types of dialogues, such as negotiation, inquiry, persuasion, information seeking, deliberation, and quarrel, might be conducive to the accomplishment of different real-world objectives (Walton, 1998). The same dialogue type and

sequence of moves might be judged appropriate in one context but not in another. An expert-consultation dialogue, with appropriate norms, might make sense when one participant has significantly more knowledge and experience than the other; but an information seeking dialogue, with different norms, should be used when one party merely has information that the other party lacks.

Dialogue theory does not provide an adequate solution for when to stop a dialogue. For example, in the critical discussion that we looked at above, there was no limit to the number of challenges and responses, hence, to the number of features and alternative mental models that might be considered. Participants need to know when challenges should come to an end and the current best conclusion acted upon, and this usually depends on external context. For example, the same dialogue might justify acceptance of a conclusion when there was limited time or information to make a decision, but might be insufficient to justify a conclusion when more information or more time is available or the stakes are more serious.

Dialogue theorists address the issue of winning and loosing in terms of clear-cut cases, in which either the proponent retracts her original assertion or the opponent withdraws her challenge. Real cases may not always be so easy. Time constraints may bring a dialogue to an end before definitive closure is achieved. In such cases, it is necessary to determine which position was superior at the time the dialogue came to an end, taking into account the opportunities that the participants had to challenge one another. This requires judgments about the relative reliability of different belief formation processes as well as the coherence of the alternative mental models with a large store of background information.

According to van Eemeren and Grootendorst (1992), decisions of these kinds take place during the opening stage and the concluding stage of the dialogue, rather than during the argumentation stage. For example, the type of dialogue should be agreed upon between the participants at the beginning of the dialogue, and the concluding stage determines when the dialogue ends and who won. Segregating them into different stages suggests that these decisions are qualitatively different from argumentation proper. But dialogue theorists do not address how the decisions should be made. Placing them in different temporal stages is quite artificial and only makes matters worse, since it eliminates the possibility of continuous review of the dialogue based on new information acquired during argumentation. Such information might lead to a shift from one type of dialogue to another (Walton, 1998), or it might change the estimation of how the risks of further delay balance out the costs of an incorrect conclusion, and thus affect the decision of when to stop. A more promising direction is to introduce elements of *externalist* models, which take into account likely outcomes and their associated impact on objectives.

To help dialogue theory bridge the gap between internal and external concerns, it is necessary to provide a third role, that of a *judge*, in addition to those of proponent and opponent (Figure 6). All three of the issues just discussed belong among the duties of the judge. The judge

evaluates the reliability of alternative types of dialogues for the current context and purposes. The judge evaluates the status of the argument at any given time to determine the most plausible current position, i.e., the winner if the dialogue were to end at that moment. And finally, the judge continuously weighs the value of continuing a particular dialogue versus the value of stopping and committing to the most plausible current position.

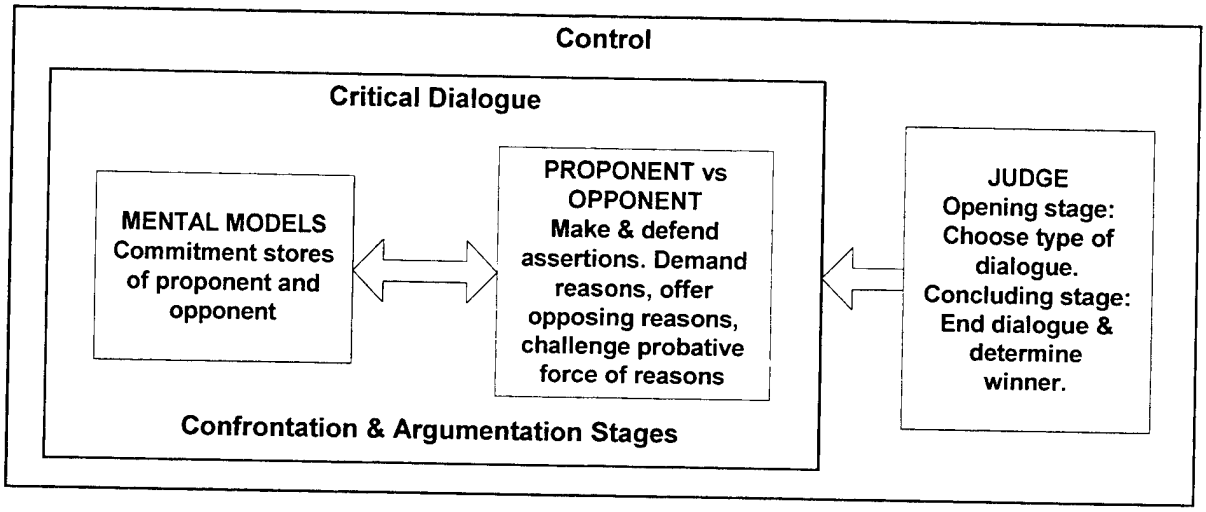

FIGURE 6: Three part model of critical thinking in terms of stages and roles in a critical dialogue.

Figure 6 shows that each component of our critical thinking model (Figure 1) corresponds to a dialogue theory concept. As we have seen, mental models correspond to the commitment stores of proponent and opponent; critical dialogue corresponds to the argumentation between proponent and opponent in which the mental models are evaluated and improved; and the judge determines the overall reliability of the process and regulates it accordingly. The judge is subject to the same capacity limitations as the proponent and opponent, of course, and will not generally *optimize* strategy choices. Rather, in accordance with the principles of bounded rationality (Simon, 1997; Gigerenzer & Selten, 2001), the judge will become adapted through experiences of success and failure in the use of various cognitive processes and mechanisms in different contexts. The judge may select and regulate belief forming strategies based on relatively automatic processes shaped by experience, or may evaluate the reliability of different strategies by explicit reasoning. The common core of the judge's functionality is judgment about the trustworthiness of a cognitive faculty from a standpoint that is external to that particular faculty.

The introduction of a reliability-based judge has another advantage. It generalizes critical thinking beyond the evaluation of explicit reasoning or critical dialogue. Other belief-generating faculties, such as perception, recall, and recognition can also be assessed in terms of their reliability, even though they do not themselves involve reason-giving and critiquing. Thus, we

can think of the judge as evaluating not only the reliability of different dialogue types, but more generally, evaluating the effectiveness and efficiency of alternative cognitive faculties, and decision making and problem solving strategies. In some situations, taking time to reason may not be the best solution.

CONCLUSIONS: WHAT ABOUT CRITICAL THINKING IN THE ARMY?

It is appropriate now to summarize some of the implications of this theory for the challenges we laid down at the beginning. Here again are some of the potential difficulties of implementing critical thinking training in the Army context:

IS CRITICAL THINKING CONSISTENT WITH TACTICAL BATTLEFIELD CONSTRAINTS?

- Will critical thinking on the battlefield take too much time? Would that time be put to better use gaining a jump on the enemy?
- Will critical thinking result in a loss of the confidence necessary for decisive leadership and action? Will it undermine the "will to fight"?

The external layer of critical thinking, i.e., the assessment of reliability, is the source of a stopping rule for the process of challenging and response. It demands that the critical thinker stay focused on real task objectives. Reflective reasoning is one tool among others, including recognitional decision making, and should be used when and only when it will increase the odds of success. There are, however, many examples in which a little time spent thinking saved much more time in execution (e.g., Cohen & Thompson, 2001). Because of the external layer, however, critical thinking never involves an endless exploration of alternative possibilities with no end in sight.

The critical dialogue layer of critical thinking permits a variety of different reasoning styles that differ in how free-ranging the consideration of alternative possibilities may be. In time stressed situations, a more constrained reasoning process, in which basic assumptions are not questioned, leads to more rapid decision making. Explicit recognition of the mode of dialogue that has been adopted among team members may actually speed up communication and reasoning. Confidence is typically increased by a disciplined exploration of relevant and significant alternative possibilities.

IS CRITICAL THINKING CONSISTENT WITH OTHER BATTLEFIELD SKILLS?

- Will critical thinking skills trump experience or leadership qualities on the battlefield, which might in fact lead to better decisions?
- Will critical thinking be too "critical"? Will it stifle innovation or the development of new tactics and techniques?

The external layer of critical thinking involves choosing the most reliable process for a given decision. For experienced leaders, the most reliable method sometimes involves trust in their own gut feel for a situation.

As far as innovation goes, the dialogue layer of critical thinking is not "critical" in a narrow sense. It not only evaluates possibilities, it generates *new* possibilities. The space of alternatives is constantly changing as a result of the challenge and response process. The construction of these mental models does not necessarily proceed in a rigid step by step fashion. In the context of a permissive critical dialogue, any assumptions may be questioned and retracted. Alternative mental models are evaluated in terms of their overall coherence with a system of beliefs. The interconnectedness of beliefs in a coherence-based system can lead to rapid, creative shifts in the understanding of a situation, similar to the *paradigm shifts* that T. Kuhn (1996) describes. Such shifts may involve the simultaneous modification of numerous assumptions, beliefs, and plans.

Is Critical Thinking Appropriate for Military Organizational Structure?

- Will critical thinking encourage inappropriate initiative? Will it disrupt the chain of command and degrade coordination and synchronization on the battlefield? Put another way, is the Army too centralized and hierarchical for critical thinking to flourish?
- Will critical thinking hinder the development of trust in diverse, multi-cultural teams because it is "Western, masculine, individualistic, adversarial, and coldly rational" (Atkinson, 1998, p.121).

Critical thinking is most suited to situations in which individuals have significant autonomy and responsibility, and such situations are likely to increase in frequency in future Army missions. But critical thinking can function at many different levels, e.g., in the performance of virtually any non-routine task. The dialogue layer provides a series of dialogue types that vary in the extent to which assumptions are questioned. The higher the level of initiative, the more far-reaching the exploration of alternatives might be. But critical thinking at some level is nearly always appropriate.

As for cultural diversity, the dialogue layer provides a framework for classifying different styles of interaction. This framework may lead to more stable and better calibrated expectations among individuals from diverse cultural backgrounds. It also allows for the evolution of new styles of dialogue that may be better suited to a specific team or context.

Will Critical Thinking Fit into Army Training?

- Are there "right answers" in critical thinking? If so, isn't this just a new phrase for teaching doctrine and tactics, which we already do? If not, what good are skills that can't be evaluated? How can we know they will improve performance?

- Will critical thinking instruction consume too much training time? How will we persuade instructors to provide that time? Does critical thinking require technical training in logic or decision theory? Does it require stand-alone courses? How will we persuade students to devote their time to the study of critical thinking?

Metrics for critical thinking performance focus on process rather than product. Both the dialogue layer and the reliability layer evaluate belief acceptance in terms of the processes that led to it, and each provides relatively unambiguous evaluative criteria. Metrics for a successful dialogue measure the degree to which an actual conversational exchange corresponds to the profile of the relevant type of dialogue. For example, was disagreement acknowledged? Were challenges sought out? Were they answered? Metrics for reliability include the probability that the selected cognitive faculty or communicative process will support the objectives of the task under the prevailing conditions. For either dialogue or reliability based measures, a decision may be good even though the outcome happens to be bad, and conversely, a decision may be bad even though there was a lucky outcome.

Each layer of critical thinking is associated with a specific set of skills and training objectives. For example, the innermost, mental model layer involves the ability to generate possibilities based on existing elements, the ability to add dimensions to the space of situations, and the ability to evaluate and compare mental models in terms of their internal coherence and compatibility with background knowledge. The dialogue layer involves awareness of different types of dialogues with different rules for identifying conflicting positions, for challenging and retracting assumptions, and for "winning" and "loosing." The outermost, reliability layer requires an awareness of strengths and weaknesses of different cognitive processes or faculties, and the ability to make appropriate choices based on the circumstances, e.g, between recognitional decision making, creative brainstorming, or reflective reasoning.

Critical thinking skills are best acquired in the context of actual decision making. Thus, critical thinking training may be incorporated relatively seamlessly into subject matter coursework, exercises, and field training. Students may be taught through coaching, hints, feedback, and example, in addition to explicit instruction (see Cohen, at al., 2000a). Critical thinking training can also be given as a standalone course, as long as concrete exercises (e.g, tactical decision games) are emphasized. None of the relevant skills requires specialized training in formal logic, decision theory, or philosophy. Nevertheless, these are skills that need some explicit attention, and thus it would be best for instructors to receive some specialized training. A useful first step might be the development of a brief, intensified critical thinking course for instructors.

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The Role of Critical Thinking in the Performance and Training of Command Teams

Daniel Serfaty

Aptima, Inc.

ARI Workshop on Critical Thinking for Battle Command
Fort Leavenworth, November 30, 2000

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Outline

- Command Teams
- Team Performance
- Team Training
- Team Critical Thinking

Daniel Serfaty's paper is not available and a copy of his slide presentation is being substituted

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Team Performance R&D

	Project	A2C2 Joint Task Force	DD21 Next Gen. Ship	AWACS Airborne C2 System	WOCT Ground C2 System	UCAV Auto. Combat Vehic.	CODE Next Gen. Carrier	JFACC Air Component Command	DCD Decision Centered Design	Global Large Scale Wargame
	Application									
Mission/Org. Analysis	Optimized Mission Process	P	P	P		P	P	P		
	Workload Assessment		P	P	P			P	P	
	Information Flow/ Communication		P	P	P			P		P
Architecture Design	Resource Allocation	P	P		P			P		
	Team Optimized Des...	P	P	P		P		P		P
	Function Allocation		P	P		P		P	P	
Team Perform. Improv. Approaches	Training Requirements	P			P					
	New Technology Insertion		P	P			P	P		P
	Display Requirements			P		P	P			
	Physical Layouts		P				P			

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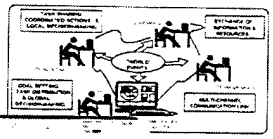
Studying Command Teams

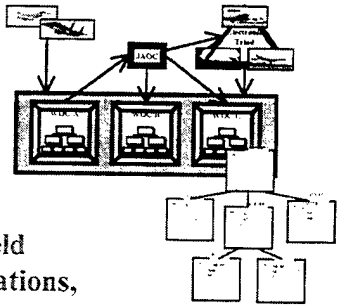
From Field to Laboratory...

- FIELD: Live performance assessment & human-engineering
  - Computer-based observer tools
  - Results inform training, performance, display design
- THEORY: Team models & constructive simulations
  - Algorithm-based team design
  - Sim.-based assessment
- EXPERIMENT: HIL Sim.-based experimentation
  - Team synthetic tasks
  - Partnerships with universities, industry
  - Technologies support data collection & analysis

Virtual, Team-in-the-Loop Experiments



Constructive Mission Simulation



Field Applications, Live Assessment

... and Back

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What is a Team?

- Dynamic, interdependent, and adaptive interaction
- Common goal, mission, or objective
- Organizational structure of team members
- Each individual has specific tasks or functions
- Task completion requires dynamic communication of information and coordination of task activities

(Salas, Dickinson, Converse & Tannenbaum, 1992)

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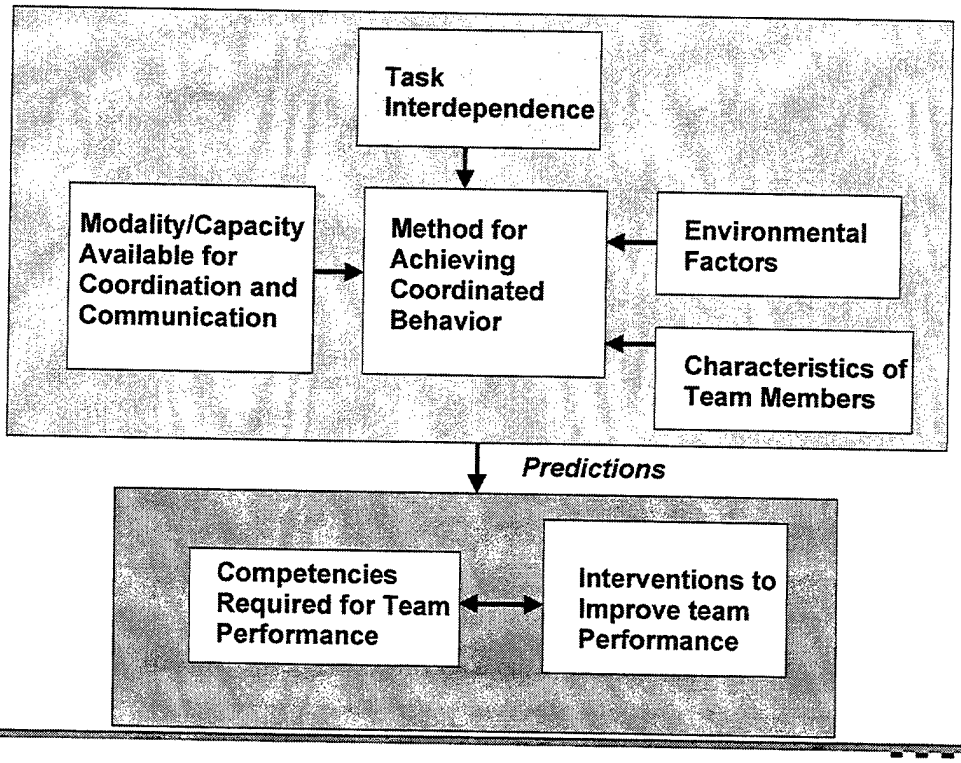
Team Framework



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Interdependence of Team Members' Tasks

- Extent of common goals
- Extent of task interdependence
- Nature of the interdependence
  - time (sequential, parallel)
  - outcome
- Precision of interdependence in space and time
- Extent of task specialization/overlap (possibility of backup)

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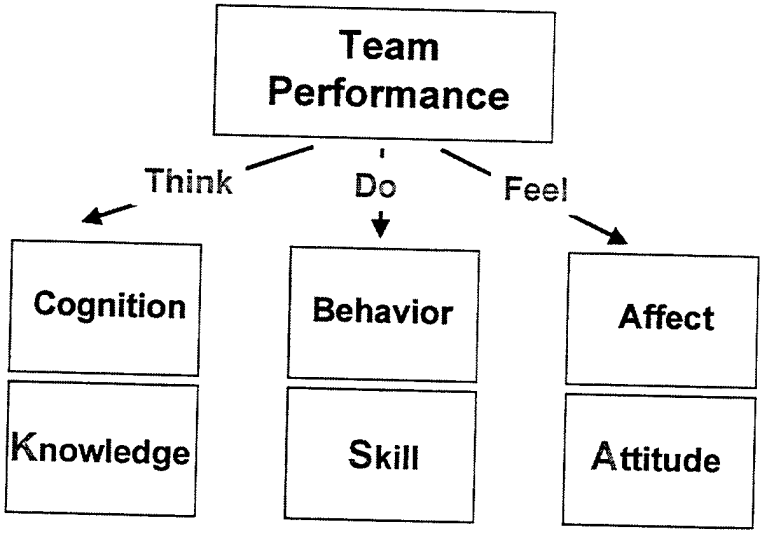
What Do Teams Do?



- Team competencies (KSA)

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Team Competencies (1/3): What Do We Know About Team Knowledge?

- Task-specific roles and responsibilities
- Knowledge of team mission and objectives
- Knowledge of team norms and resources
- Knowledge of team "state"
- Teammate characteristics (behavior adjustment)
- Shared task models
- Cue ←→ Strategy association

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Team Competencies (2/3): What Do We Know About Team Skills?

- Conflict resolution
- Task assertiveness
- Leadership
- Supporting/back-up behavior
- Mutual performance monitoring
- Coordination & communication
- Adaptability: behavioral discretion

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Team Competencies (3/3): What Do We Know About Team Attitudes?

- Collective orientation
- Mutual trust
- Importance of teamwork
- Team cohesion
- Shared vision
- Collective efficacy
- Team orientation (morale)

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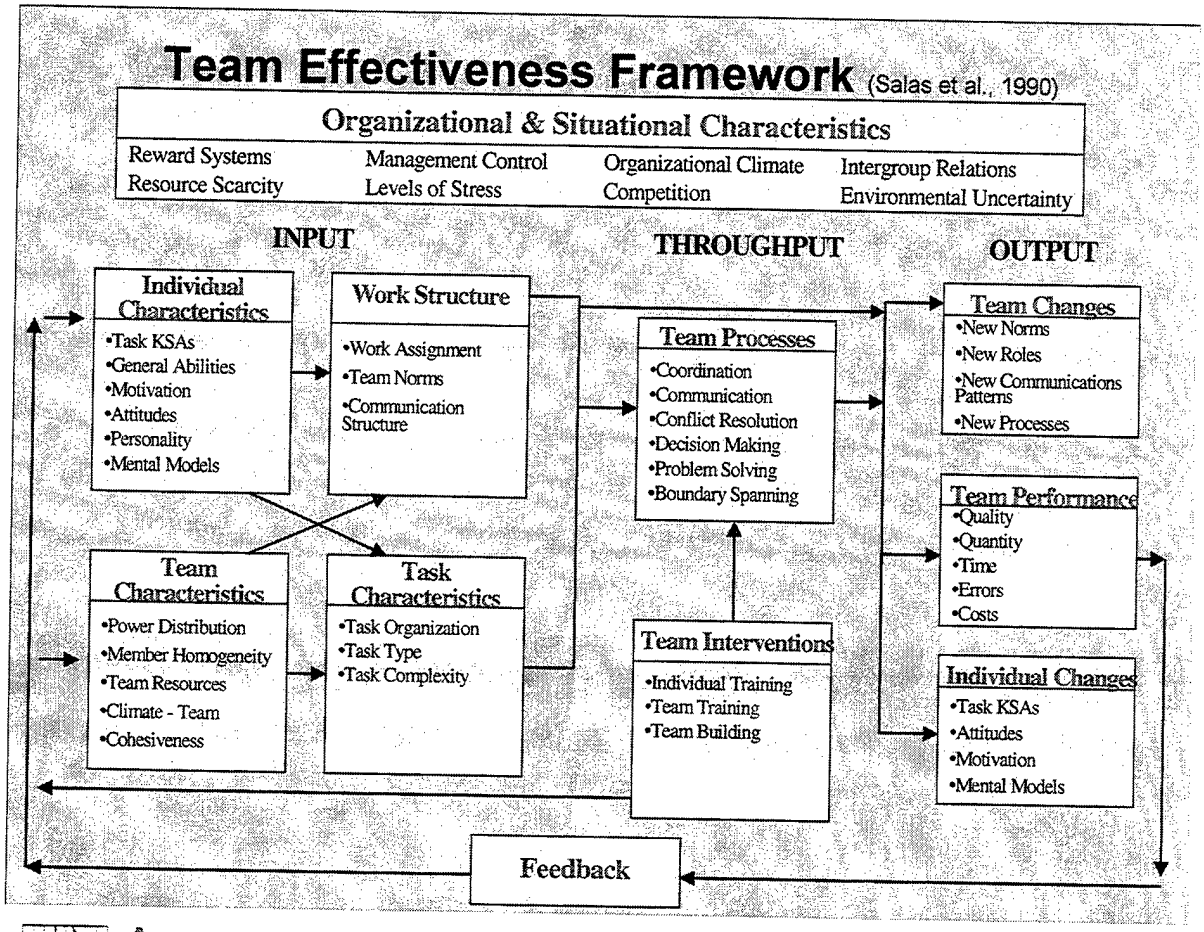
Key Things We Learned About Command Teams

- ✓ Good individual skills are necessary, but not sufficient, to high team performance
- ✓ Teamwork skills are distinct from taskwork skills
- ✓ In high-performing teams, team members:
  - Anticipate each other's needs
  - Practice pro-active back-up behaviors
  - Have a dynamic shared "mental model" of the task and the team
  - Provide continuous mutual feedback on performance
  - Adapt, adapt, adapt...

Question: How would critical thinking enhance or support these behaviors?



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Meta Network Approach to Team Representation

	People	Knowledge	Resources	Tasks	Organizations
People Relation	**Social Network** *Who knows who*	**Knowledge Network** *Who knows what*	**Capabilities Network** *Who has what resource*	**Assignment Network** *Who does what*	**Work Network** *Who works where*
Knowledge Relation		**Information Network** *What informs what*	**Skills Network** *What knowledge is needed to use what resource*	**Needs Network** *What knowledge is needed to do that task*	**Competency Network** *What knowledge is where*
Resources Relation			**Substitution Network** *What resources can be substituted for which*	**Requirements Network** *What resources are needed to do that task*	**Capital Network** *What resources are where*
Tasks Relation				**Precedence Network** *Which tasks must be done before which*	**Market Network** *What tasks are done where*
Organizations Relation					**Inter-Organizational Network** *Which organizations link with which*

Source: Kathleen M. Carley, Carnegie Mellon University

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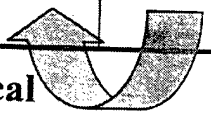
State of Team KSA

	Knowledge	Skill	Attitude
Research	+	++	+/-
Measures	-	++	+/-
Training	+/-	++	-



Critical Thinking

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To Enhance Team Performance

1 Change team membership

2 Modify team tasks, workflow, structure

3 Improve team interactions/processes

4 Build team capabilities /competencies

5 Enhance individual team member capabilities

6 Provide support, resources, performance aids

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Outline

- Command Teams
- Team Performance
- Team Training
- Team Critical Thinking

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Examples of Proven Team Training Interventions (TADMUS-NAWCTSD)

- Team Self-Correction
- Team Leader Training
- Team Adaptation and Coordination Training (TACT)
- Stress Exposure Training
- Cross-training
- Team Dimensional Training
- ....

*"You **can** teach old dogs some new tricks!..."*

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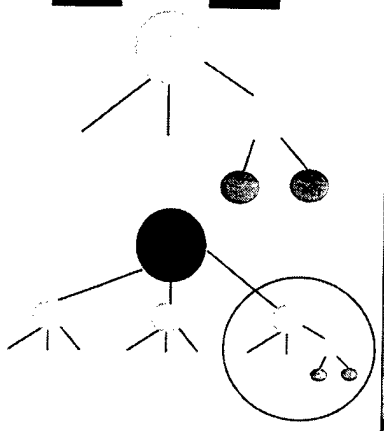
TACT Premise: Commanders Adapt

- Individual
  - Analytical ←→ Intuitive Decision-making
  - Deductive ←→ Inductive reasoning
  - Recognition ←→ Metacognition
- Team
  - Centralized ←→ Decentralized Information
  - Authoritative ←→ Delegative Command
  - Explicit ←→ Implicit Coordination
- Organization (Team of Teams)
  - Synchronization ←→ Autonomy
  - Function-Oriented ←→ Mission-Oriented
  - Combat ←→ OOTW



Team Adaptation: Enabled by Team Critical Thinking

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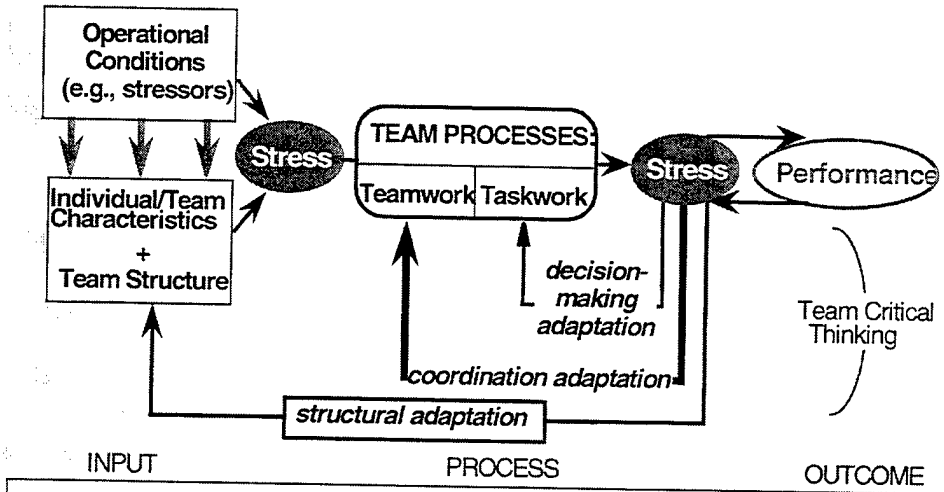
Model: Levels of Adaptation to Stress



***PREMISE:** Well-trained teams cope with stress through internal mechanisms of decision strategy adaptation, coordination strategy adaptation, and structural reconfiguration, in an effort to keep performance at the required level while maintaining stress below an acceptable threshold.*

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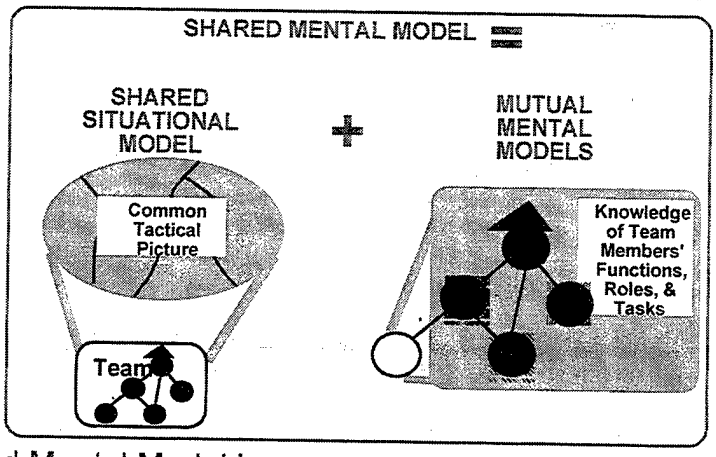
Enhancing Shared Mental Models and Team Coordination



- A Shared Mental Model is a necessary, but not a sufficient, requirement for superior team performance (need teamwork skills)
- Implications for TACT Team Training
  - Implicit-Explicit Adaptive Coordination
  - Leader's Situational Update

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TACT Training Model

- Train team members to recognize
  - Stressors in the tactical environment
  - Signs of stress in the team
- Teach the team alternative communication and coordination strategies
- Train the team to match each coordination strategy to conditions of the team environment
- Practice and feedback this adaptive behavior at the team level
- Add leader's situation updates to periodically calibrate the team

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Team Performance Measures

Core Elements of Measurement Approach

Why?

Driven by targeted questions:

- Team organization and distribution of roles and responsibilities
- Impacts of new technologies and decision support
- Team communication and coordination

What?

Measure both outcome and process:

- "Make the right decisions"
- "Make the decisions right"

Example: Teamwork processes
- Communications
- Leadership
- Compensatory behavior
- Information Exchange

How?

Mix of measurement sources:

- Participant measures
- SME observers (both operational and behavioral)
- Simulation-based measures

At What Level?

Three levels of analysis:

- Individual
- Team
- Team of Teams

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Metrics of Team Communication & Coordination

Measures of Flow of Information & Communication

- Information Filtering
- Information Production
- Direction of Communication
- Type of Communication
- Subject of Incoming Messages
- Subject of Outgoing Messages
- Message Classes
- Cueing and Buffering Messages

Analysis

Second Order Metrics of Information Management and Coordination

- Information compression ratio
  - Relationship between incoming and outgoing messages
- Quality ratio
  - Quality of information filters
- Anticipation ratio
  - Measures staff's ability to anticipate information needs of others
- Push-Pull Ratio
  - Number of sent message contrasted with requests for information
- Pro-action ratio
  - Staff ability to initiate transfers of information as opposed to responding to requests only
- Bottlenecks

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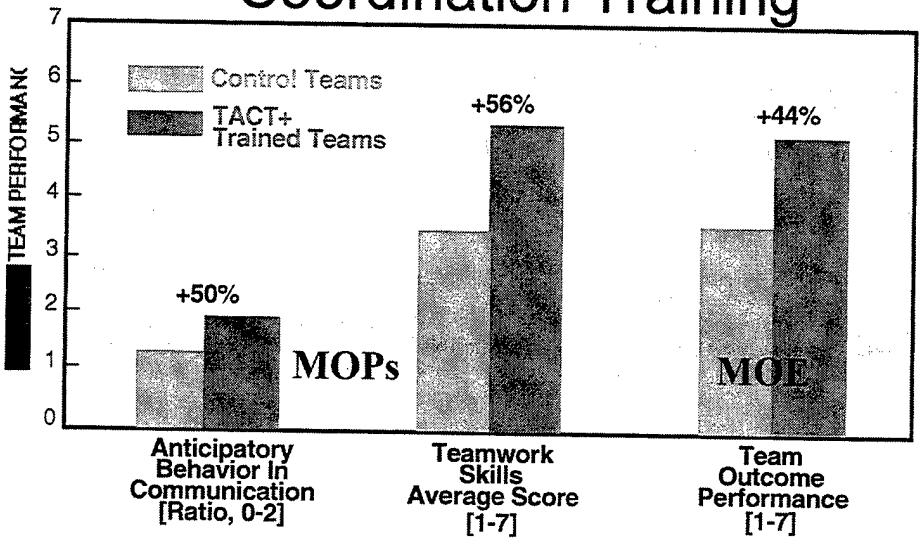
Team Adaptation & Coordination Training



Team adaptive coordination strategies are performance-enhancing and trainable (TACT/TADMUS)

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Outline

- Command Teams
- Team Performance
- Team Training
- Team Critical Thinking

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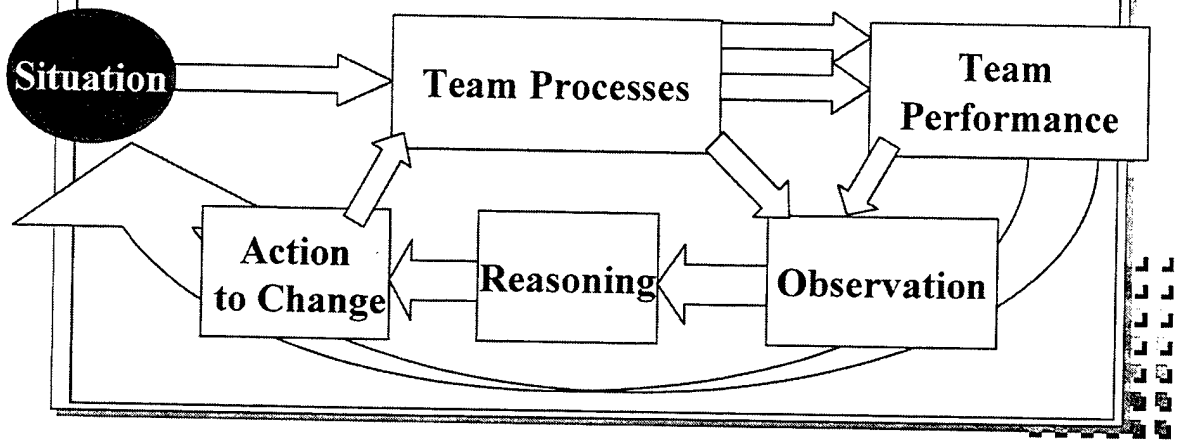
What is Team Critical Thinking?

- Control process by which teams:
  - Observe their own performance,
  - Reason about themselves and
  - Consequently act to modify the team processes that produce their performance



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Three Key Decisions Specific to Critical Thinking in Teams

- Decision to Communicate
- Decision to Coordinate
- Decision to Reconfigure

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The Decision to Communicate

- Communications dual purpose:
  - Transfer of information
  - Update of each other's mental models
- Where is the source of the info I need?
- Who could benefit from the info I have?
- Key concepts:
  - Organizational knowledge
  - Information state awareness
  - Conflict resolution

How can critical thinking help align team members' understanding of their information, tasks, and goals through proper team communication?

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The Decision to Coordinate

- Coordination: Management of overlap among team members
- Four Dimensions: Goals, Resources, Information, and Tasks
- Key Concepts:
  - Implicit Coordination
  - Anticipation
  - Workload distribution

Is critical thinking the principal ingredient for team adaptive coordination?

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Team Action Coordination

Based on Observation

- Depends on
  - amount of visual and auditory information available about teammates (co-located versus distributed teams)
  - communication channels available
  - need for backup behavior based on overload

Based on Communication

- Depends on
  - availability of common picture of the situation
    - -- different pictures among teammates require push/pull of information
  - need for team leader to direct action
  - availability of communication channels

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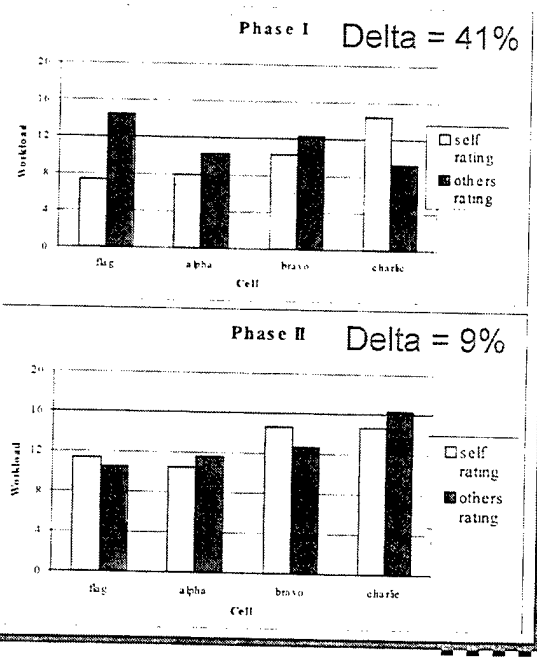
Example: Team Workload & Awareness Across Team Members

- Average workload increases 30% as operation progresses
- Pre-training: Large discrepancy between self- and perceived workload by other cells
- Post-training: More accurate mutual perception of workload

Common Operating Picture → Calibrated Team



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The Decision to Reconfigure

- Outer Loop of Adaptation
- Detecting the cues and needs for change
- Understanding the paths to new structures
- Key concepts:
  - Congruence
  - Organizational inertia
  - Organizational learning
  - Dynamic reconfiguration

Can team structure be designed to support the practice of team critical thinking?

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Summary

- Significant performance and training research for military command teams
- Very little research in critical thinking in teams
- Multiple team roles and team structures render the problem of team CT training more complex
  - Distributed teams
  - Virtual teams
  - Ad hoc teams
  - Vertical and horizontal structures

Complexity and diversity of military missions demand adaptive teams of warfighters capable of thinking about the way they think as teams

A SIMULATION TOOL FOR CRITICAL THINKING TRAINING[1]

MARVIN S. COHEN
COGNITIVE TECHNOLOGIES, INC.

COMPUTATIONAL LIMITS AND ATTENTION SHIFTING

The development of training system technology that we will discuss here is part of a larger research effort, in which we are trying to understand and simulate the structure and dynamics of human cognition and decision making processes. In doing this, we are exploring the linkages among several fields and building new models that are informed by data from each of these fields. Our aim has been to integrate high-level cognitive modeling, connectionist knowledge representation, and methods from optimal control (specifically, approximate dynamic programming).

This work represents a synthesis of the Recognition/Metacognition theory (Cohen et al., 1996, 1998, 2000a, 2001) with work on computer-based inference within the Shruti system, by Professor Lokendra Shastri, of the Computer Science Department, University of California at Berkeley (Shastri, 1992, 199a, 199b; Shastri et al., 1993, 1996, 1997, 1998). The immediate goal of this work was to develop a tool that can perform rapid recognitional inferences and planning within a large (expert) belief network, exemplify human limitations on computational resources and attention; and implement metacognitive control process that regulate recognitional processing, help overcome computational limitations, and deal with uncertainty. Such a tool could form the basis, in subsequent research, for the development of an adaptive training system.

According to the Recognition/Metacognition theory, decision makers structure complex and voluminous knowledge about their world into causal models that enable them to rapidly generate coherent interpretations and plans in response to an influx of new evidence and observations. We model these rapid recognitional processes using Shruti, a connectionist architecture for *reflexive* inference. Critical limits on dynamic access to long term memory (LTM) emerge naturally from the computational structure of Shruti and the neuro-biological constraints it respects. These limits effectively insist that not all information known by the agent can be brought to bear at the same time. One of the key differences between experts and novices is in *how* they structure knowledge to manage these resource limitations and apply the appropriate information during reasoning.

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[1] This work was partially funded by Contract No. DASW01-97-C-0038 with the Army Research Institute. Dr. Sharon Riedel was the technical officer. The research was also independently funded by the Office of Naval Research (Contracts N00014-95-C-0182 and N00014-00-M-0070) and the National Science Foundation (Contract DMI-9861411).

The existence of such limits means that inference and planning processes must be capable of dynamically determining the scope of active human memory from which they draw at any given time, and of remaining coherent within those limits. These changes of scope underlie the fluidity with which a reasoner is able to *focus* limited computational resources at different levels of spatial and temporal abstraction (the chunking problem in AI), and extend planning horizons from moments to years and back to moments. At the same time, this need for fluid changes in focus introduces the necessity for an adaptive dynamics of executive *attention*. The mechanisms of attention shifting, in turn, form a developmental basis for acquiring skilled *metacognitive* behaviors, which monitor and regulate recognitional processing.

According to the model described by Cohen et al. (2000a), metacognitive processes guide the focus of attention within active memory. Studies by the project team and others suggest that these metacognitive processes include monitoring recognitional results for different kinds of uncertainty, including gaps in knowledge, conflicting evidence or goals, and unreliable assumptions; attempting to fill gaps, resolve conflicts, and evaluate assumptions, e.g., by generating and considering alternative hypotheses to explain evidence and alternative plans to achieve goals; and regulation of the time taken for reflection versus immediate action, based on the costs of delay, the stakes, and the degree of uncertainty. Our computational research suggests that these metacognitive processes may develop naturally as extensions of skilled attention-shifting behaviors within a resource-limited active memory. Metacognition enables reasoning about highly mediated relationships in long-term memory, i.e., interdependencies that are implicit in long-term memory, but which are too distant to combine to influence decisions. Metacognitive processes thus forge more distant connections and introduce a wider perspective within a computationally constrained reasoning process.

We use Shruti to model both rapid reflexive processes and the reflective processes that monitor and regulate them. In this way, the resource limitations that Shruti implies are shared across reflexive and reflective processing. Therefore, a *reflective* decision maker achieves less in any particular cycle of *reflexive* processing, but may receive a net benefit by extending the span of reflexive processing across multiple cycles of attention shifting.

APPLICATION FOR TRAINING

The great promise of computer-assisted training is its potential to track the progress of individual students in real time. Feedback and training content might be adapted to individual students on at least three different levels: (1) at the lowest frequency, to enduring personal cognitive styles and overall goals; (2) at an intermediate rate of change, to current level of ability; and (3) at the most transient, high-frequency level, to the momentary state of strategy execution, fatigue, attention, or stress. A key technical hurdle at all of these levels is flexibility. Once the knowledge base for a particular problem situation has been coded, the feedback tools and adaptation policies should be able to recognize and evaluate a range of unacceptable and

acceptable *variations* in student responses, at various levels of abstraction, and over long and short time periods, without requiring that all variations and their significance be explicitly anticipated by training designers and scripted in advance in the training system. *Flexible*, adaptive training of this kind requires an advanced computer-based model of the targeted decision making skills, going beyond procedural rules for predicting and/or tracking molecular responses. A bonus of this kind of flexibility will be its extensibility to new exercises within the same situation and to new situations in the same domain.

In the rest of this paper, we provide an overview of some of the distinctive features of the simulation tool, on both the recognitional (reflexive) and metacognitive (reflective) sides, and indicate how they support one another's functioning. We will illustrate how they work in a simple example. We will also briefly outline how these features lend themselves readily to visualization within a graphical user interface. A more detailed account of the system can be found in Cohen et al. (2000c).

REFLEXIVE AND REFLECTIVE PROCESSING: AN EXAMPLE

In the Sanna's Post scenario, you are the commander of a reinforced rifle company (which we shall call Company A), whose mission is to provide flank security for the other companies in the battalion and to be prepared to become the main effort if necessary. At present, the other companies are heavily engaged to the east, supporting the brigade fight, and your company must prevent reinforcement by the enemy from the west. You receive a scout report that enemy supply vehicles and fuel trucks, as well as some armored vehicles, are in the vicinity of the town of Sanna's Post. There is a road through Sanna's Post that runs eastward to a ford over the Modder River, and from there to the area of the battalion fight (Figure 1). What do you do?

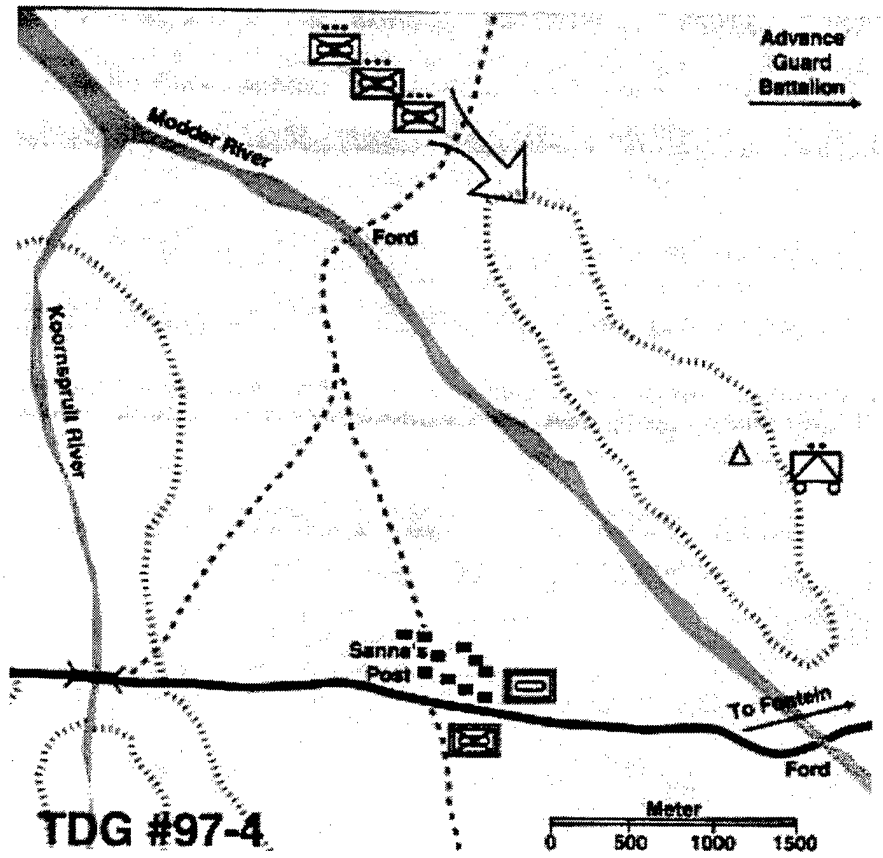

FIGURE 1: Sanna's Post scenario map.[2]

Figure 2 represents a possible initial recognitional response to this situation. It will help us introduce some important basic features of Shruti's model of recognitional processing. Figure 3 and Figure 4 represent the results of shifting attention under the control of the reflective system, and will help us discuss how reflective, metacognitive processes monitor and regulate recognition.

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[2] MacIntyre, Capt Douglas J. "Tactical Decision Game #97-4: Battle of Sanna's Post." *Marine Corps Gazette*. April 1997. Quoted with permission by Steve M. Crittenden, Managing Editor, *Marine Corps Gazette*, Box 1775, Quantico, VA 22134, 4 Feb 99.

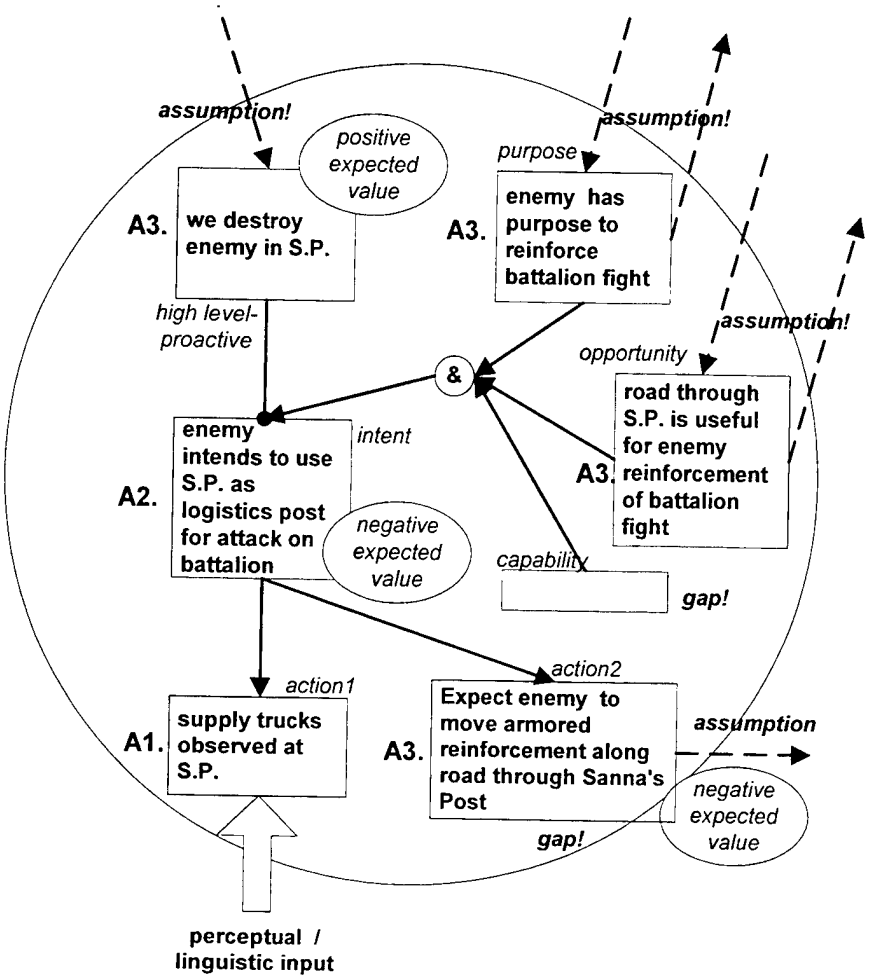

FIGURE 2: Initial recognitional response to perceptual input in the Sanna's Post example. Attention is focused by perceptual inputs on supply trucks at Sanna's Post (shaded box). The circle represents the spread of activation, and labels A1, A2, and A3 represent the order in which nodes receive activation. Intent mental model components are also labeled (*purpose, intent, opportunity, capability, action*).

BASIC FEATURES OF THE REFLEXIVE SYSTEM

Shruti enables a connectionist representation of causal mental models. In Figure 2, the perception of trucks at Sanna's Post activates knowledge in the commander's long-term memory. Some of this knowledge is in the form of an *enemy intent* mental model with four active components: purpose, opportunity, intent, and actions (Cohen et al., 2000a). The long-term memory of the commander includes a belief that the enemy's *purpose* is to reinforce the fight against the battalion, and that a likely *opportunity* to do this is along the road through Sanna's Post. For these reasons, the enemy *intends* to use Sanna's Post as a logistics base, and the supply vehicles indicate that the enemy has already taken *action* to implement the intent.

Additional *actions* that might be expected based on this intent are use of the road by enemy armored columns heading east.

Weights in the reflexive system can be adapted to the statistical properties of the environment through experience. The Shruti simulator tunes network weights and rule-strengths via supervised learning, using a form of backpropagation. These weights reflect the co-occurrences of concepts that define *mental models*.

Reasoning proceeds both backward, to find explanations, and forward, to generate predictions. For example, the perception of trucks at Sanna's Post activates *explanatory* beliefs regarding intent, purpose, and opportunity. These in turn activate a *prediction* of future events, i.e., the appearance of armored vehicles on the road. Combination rules in Shruti capture predictive reasoning and abductive reasoning, as well as taxonomic/semantic reasoning. As a result of the latter, rules framed in terms of general categories can be activated by information about instances of those categories.

The system propagates values as well as belief, and settles on actions at the same time as it settles on a situation interpretation. Changes in belief lead to the activation of goals, and the activation of goals influences the direction of attention to other beliefs, and ultimately the release of action. As we have seen in Figure 2, the observation of trucks leads to a prediction (i.e., enemy use of the road to reinforce the battalion fight), which has negative expected utility. The utility of that predicted event changes the salience of beliefs; in particular, it heightens the degree and persistence of activation of all the causes of the event, including enemy intent, purpose, and opportunity. Thus, *belief* propagated from an event to its causes is heightened by the (positive or negative) utility of the event. In parallel, *utility* itself propagates to causally related events over which the decision maker might have some control. For example, the negative expected utility of enemy reinforcements on the road leads to activation of positive expected utility for any friendly action that can prevent it from being carried out. One such action is destroying the enemy in Sanna's Post. Metacognitive processes, as we shall see, are likely to shift attention to this possible action.

The reflexive system uses dynamic variable binding to keep track of objects and the roles they play in relations. This feature is virtually unique among rapid, parallel systems. In this example, it enables the system to know that the same entities (i.e., Sanna's Post, the road, the enemy) recur in different parts of the inference, i.e., are bound by different predicate nodes of the inference network. These identities are necessary for the validity of the conclusions.[3] Traditional models of associative processing support "associations of ideas," but do not support the specific, relational inferences that people quickly and accurately arrive at. For example, without object tracking and enforcement of identity constraints by rules, it would be possible to conclude that

[3] In Shruti, object identity is represented by temporal synchrony of firing at nodes in different places in the network, and identity constraints on the application of rules are enforced by temporal pattern matching.

because trucks were observed at *Sanna's Post*, the enemy intended to use *Fontain* as a logistics post. It might be possible to infer that because this force intended to use Sanna's Post for logistics, that another force intended to use a different local road to move armored vehicles.

The reflexive system uses parallel processing to achieve scalability and speed. Human recognitional reasoning is extremely rapid over a very large knowledge base, on the order of 500 milliseconds or less. The parallel character of reflexive processing is illustrated Figure 2. The node labeled A1 is the first to be activated, by perceptual inputs, and A2 is activated next. However, the four nodes labeled A3 are all activated simultaneously, because they are all two layers removed from the initial activation. Because computations at both the reflexive and reflective levels are parallel, time increases as a linear function of the size of the network.[4]

Predictions regarding resource constraints derive naturally from the representational and computational features of the system. These features account for limits on the amount of long-term memory that can be active in working memory at one time. In Figure 2, for example, activation beginning at A1 spreads to two additional layers (A2 and A3), but no further.[5] In order to bring more knowledge into play, the commander will have to shift attention.

Shruti acquires and stores aggregated information about what lies beyond the current edge of the active network. Whenever a node is on the edge of the currently active network (i.e., the A3 nodes in Figure 2), aggregated information stored at that node comes into play, representing the *average historical effects* of currently inactive information that is linked to that node in long-term memory. Instances of aggregated historical information are labeled as *assumptions*, because the validity of inferences within the active part of the network depends on (at least implicitly) *assuming* that the aggregated, historical information in fact fits the *present* situation. Acting on such average information is a big part of what meant by "acting on habit," i.e., failing to remain mindful of the particulars of the situation. In this model, assumptions of this sort are a principal target of reflective, metacognitive monitoring.

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[4] In addition to versions of Shruti that run on serial platforms, a version of Shruti has also been implemented on a parallel machine, the CM-5, (Mani, 1995; Shastri & Mani, 1997). The resulting system can encode knowledge bases with more than 500,000 (randomly generated) rules and facts, and yet respond to a range of queries requiring derivations of depth five in under 250 milliseconds. Even queries with derivation depths of eight are answered in well under a second. We are actively exploring the possibility of mapping Shruti onto a more readily available parallel processor, such as a network of workstations (NOW), Beowulf cluster, or array of StrongARM processors. Parallel processor solutions for Shruti have been studied extensively in the context of the CM-5. The results of that research should apply especially well to a StrongARM array, which shares the extremely low message latency of the CM-5.

[5] Because Shruti uses temporal synchrony for object identify, finite bandwidth means that (i) only a limited number of objects can be tracked at any given time, and (ii) if jitter increases with the length a signal travels in the long-term memory network, accurate inference about objects (as opposed to coarser associations of ideas) is limited in depth.

Three kinds of aggregated information, or assumptions, are shown in Figure 2:

- *Prior probability of a causal explanation (e.g., purpose & opportunity).* Two of the A3 nodes in Figure 2 are possible causes of the trucks' presence at Sanna's Post, e.g., enemy purpose and enemy opportunity. The observation of trucks provides some support for beliefs about these causes, specifically, that the enemy's purpose *is* to reinforce the fight and that the road through Sanna's Post *is* a likely opportunity for doing so. To infer the new strength of these beliefs after observing the trucks, the impact of that evidence must be combined with the prior degree of belief in those causes. This prior belief is based on the past frequency with which an enemy of this type had a purpose (or opportunity) of this type. This aggregated information does not take into account specific features of the current situation, which might make it different from the historical average. For example, there may be further causal links that suggest that this will (or will not) be the enemy's purpose, e.g., aspects of enemy doctrine or the historical practice of the enemy commander,. Nodes representing these specific possibilities, even if they do exist in long-term memory, are not currently in "working memory," i.e., they have not been activated in the current network.
- *Expected utility of an event (e.g., moving armored reinforcements along the road through Sanna's Post).* One of the A3 nodes in Figure 2 is the predicted event, moving reinforcements along the road through Sanna's Post. Much of the negative utility of this event is indirect, inherited from its historical association with further events (to which it causally contributes) that are *more directly* undesirable: i.e., an increase in friendly casualties and a higher chance of the enemy's prevailing. Over past experience, the positive and negative utility from these and other subsequent events has propagated back to the precursor events. As a result, aggregated information about the expected utility of moving armored reinforcements toward the fight is stored at this event node. However, as with prior probabilities, this information does not take into account the specifics of the present situation. For example, it might even be desirable for the enemy to try to move reinforcements on that road in this situation, if expected rains are likely to make the road impassable. This information, if it exists in long term memory at all, is not currently active.
- *Feasibility of an action (attacking Sanna's Post).* Any event is a potential action or goal, when it is actually within a decision maker's power to bring about or prevent the event. Thus, expected utility propagates from a predicted event back to other events that can causally affect it and over which the decision maker might have some control. Positive or negative expected utility (unlike belief) is propagated to an event only to the degree that action to influence the occurrence of the event is *feasible*. Feasibility information is stored at an event node and consists of aggregated information about the results of trying to accomplish or prevent that event in the past. For example, in Figure 2, the enemy's intent to use Sanna's Post for logistics receives negative expected utility if it is feasible to prevent it, e.g., by destroying the enemy at Sanna's Post. Since it is on the edge of the active network, destroying the enemy at Sanna's Post receives positive expected utility only if the average outcome of attempting to destroy enemy posts of this kind has been success. Once again, this aggregated information does not take the specifics of the situation into account. There may be factors that make destroying the enemy less or more feasible than usual in this

particular situation. This information, if its exists in long-term memory, is not active in the current network.

INTERACTION BETWEEN REFLEXIVE AND REFLECTIVE SYSTEMS

Shruti provides a mechanism for shifting attention, and for the activation of additional information in long-term memory by means of such shifting. Figure 3 shows the result of shifting attention, under a metacognitive control process, from the observational inputs to one of the four *assumptions* in Figure 2. The nodes labeled B1, B2, and B3, represent spreading activation during the second attentional cycle. In this example, the decision maker focuses on the recognitional response, destroying the enemy in Sanna's Post. This shift brings into view knowledge that was previously dormant. The newly activated knowledge concerns the feasibility of destroying the enemy in Sanna's Post. Attention shifting disaggregates the historical information stored at the node (destroying enemy in Sanna's Post), by exploring the contents of the network beyond that node. In doing this, it allows the pattern of activation to adapt to the facts of the present situation that are represented in the newly activated part of the network. Attention shifting thus removes some of the reliance in decision making on "habit," i.e., historically aggregated information.

It turns out that the facts in this example are not as clear cut as the average. On the one hand, Sanna's Post is a logistics post, which is typically a weakly defended target. On the other hand, armored vehicles have been spotted there, which outgun an infantry company. This represents a conflict of evidence about the feasibility of destroying the enemy at Sanna's Post. Here we have a typical result of metacognitive critiquing and correcting (Cohen et al., 2000a): the solution to one problem (confirming or disconfirming the reliability of an assumption) leads to another problem (conflicting evidence).

Determining when and where to shift attention so as to obtain a more detailed verification of current recognitional conclusions is a key function of metacognitive strategies. In Figure 4, the commander has initiated a third attentional cycle, by shifting attention to one of the sources of the conflict: the presence of armor at Sanna's Post. The nodes labeled C1, C2, and C3 represent spreading activation in the third attentional cycle.

Shruti exhibits priming effects that preserve and integrate the results of reflexive reasoning during successive shifts of attention. The new information activated by an attention shift must be combined with information that was active before the shift. Once the decision maker has shifted attention to the armor at Sanna's Post in Figure 4, most of the initially active part of the network (in Figure 2) slides beyond the range of activation. In Figure 4, destroying the enemy at Sanna's Post is now on the edge of the active network again, but the consequences of this action (Figure 2) are now inactive. Its expected utility, however, is not simply an average over many occasions of destroying such posts. It reflects details of the present situation that were very recently active in Figure 2 and that are now *primed*. This primed information shows the

relevance of Sanna's Post to the battalion fight to the east. As a result, the expected utility of destroying the enemy at Sanna's Post is far higher than a historical average would indicate. Without priming, reflexive reasoning would be a succession of hermetically sealed windows, uninfluenced by context except through crystallized historical averages. With priming, the context of each active window exerts a real-time influence through primed information, even when it is not fully attended.

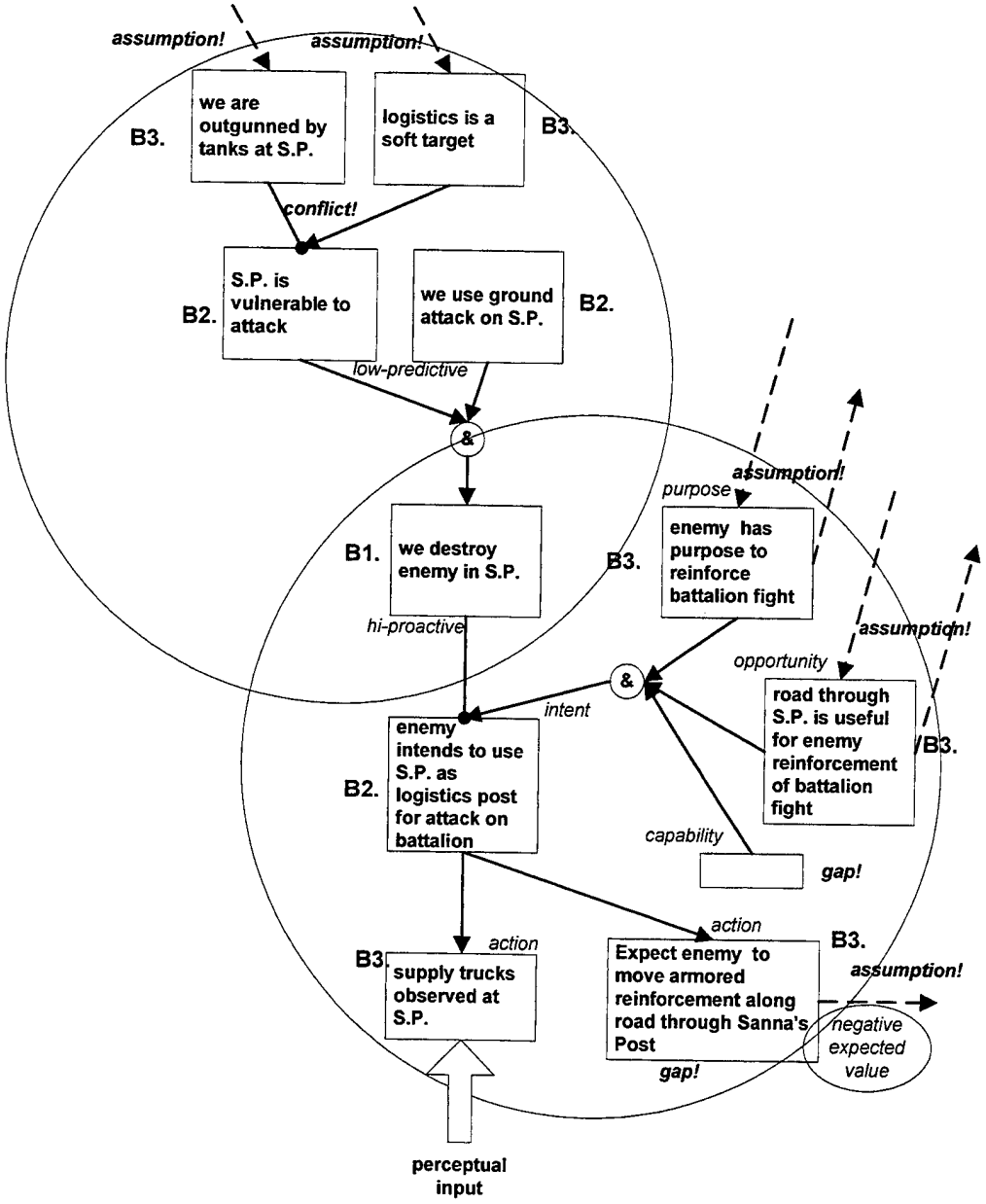

FIGURE 3: The result of shifting attention to the action of destroying the enemy at Sanna's Post (shaded node). Nodes labeled B1, B2, and B3 reflect the order of activation after the attention shift.

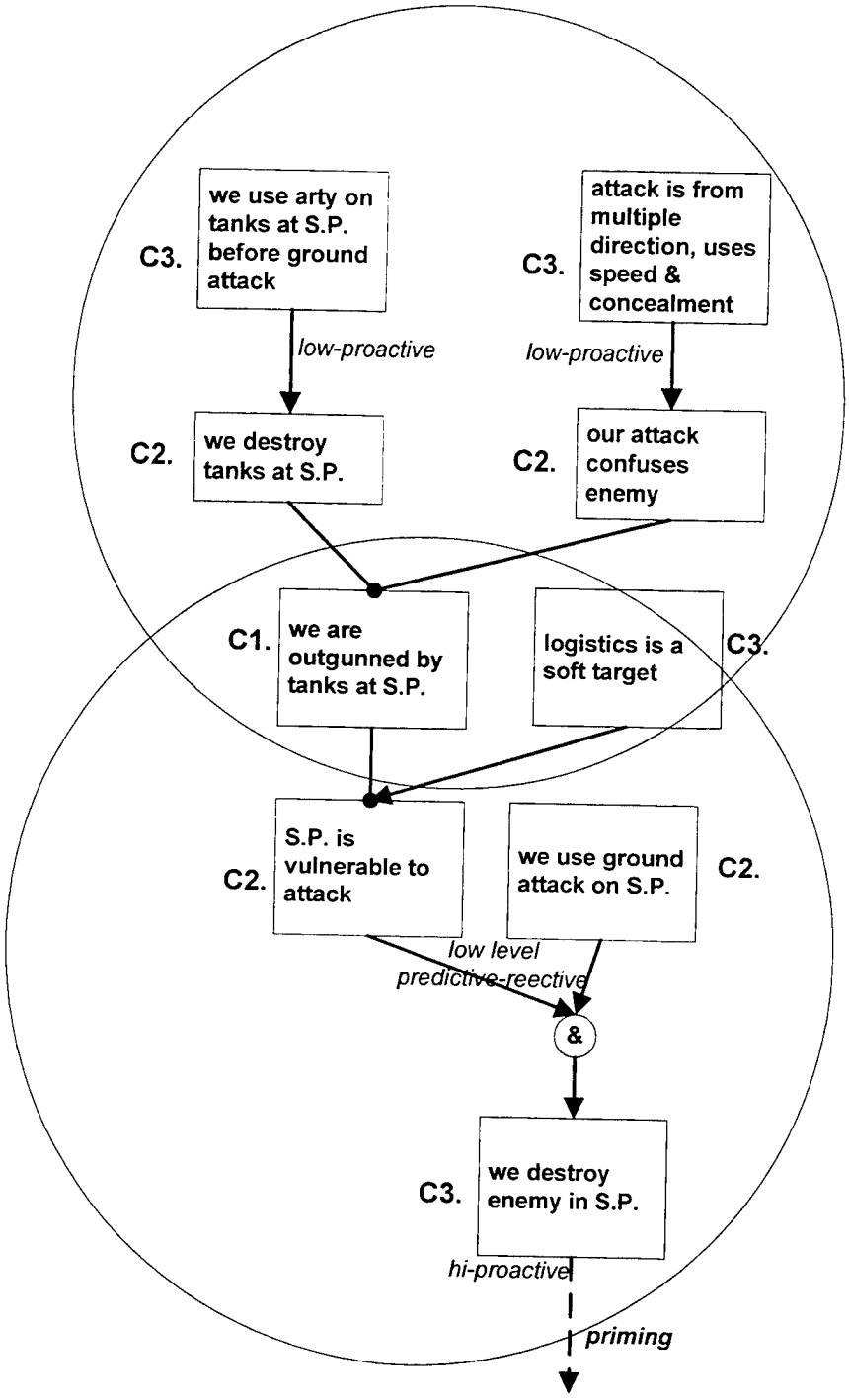

FIGURE 4: Result of shifting attention again, to belief that we are outgunned by tanks at Sanna's Post (shaded node). Labels C1, C2, and C3 represent ordering of activation of nodes after this attention shift.

Reflective and reflexive attitudes can co-exist although they compete for some of the same resources. In order to detect uncertainty in a mental model, the decision maker must adopt

a *reflective stance*. This means simply that he or she is treating at least one of the components of the currently active reflexive network (e.g., instantiated relations) as an *object*. Shruti constrains the total number of objects that can be discriminated. As a result, the more reflective a decision maker becomes, the less able he or she is to sustain dynamic discrimination of the objects in the domain, such as ships and countries. Because of this constraint on the total number of objects, during routine processing reflection will tend to be limited to the predicate in focal attention. In novel or uncertain situations, reflection can expand to include more parts of the active network and to represent evidence-conclusion relationships among these objects. Thus, the reflective stance (which objectifies statements) competes with, but can also co-exist with, the reflexive stance (which objectifies objects in the domain).[6]

The metacognitive system recognizes qualitatively different patterns of uncertainty in the active network. Decision makers respond differently when the probability of events is known (e.g., 50% chance of heads and 50% chance of tails in a coin toss) than when the probabilities are totally unknown (e.g., which of two unfamiliar tennis players will win a match; Ellsberg, 1988). Still another situation arises in which strong evidence is brought forward both for a hypothesis and against it (e.g., two well-supported theories which give different predictions for a particular experimental outcome). It seems plausible to suppose that the first case involves a different type of uncertainty (*risk*) than the second case (*ambiguity* or *ignorance*) or the third (*conflicting* evidence).

In real-world decision making, people do not reduce all types of belief and uncertainty to a single measure. Yet traditional probabilistic models have been dominated by single measures (such as probability as a measure of belief, and entropy as a measure of uncertainty[7]). Shruti provides a richer vocabulary, and a capability for more naturally representing a variety of uncertainty-handling strategies. The basis for this flexibility is Shruti's independent registration of evidence for and against a hypothesis and, analogously, the reasons for and against performing an action. This enables the metacognitive system to discriminate four qualitatively distinct uncertainty patterns that may exist at a single node at a given time:

- *Conclusion or decision*: significant activation either for or against a hypothesis but not both;
- *Incompleteness* of information: little or no activation either for or against a hypothesis (corresponding to ignorance or ambiguity)
- *Lack of resolution*: moderate amounts of activation both for and against a hypotheses, in which the sum of + and - activation is one or less (e.g., the coin toss)

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[6] Another factors that promotes co-existence is that the object discriminations that have been made reflexively are embedded implicitly in the evidence-conclusion relationships at the reflective level. These object discriminations are frozen rather than dynamically tracked, however.

[7] Entropy is, roughly, the degree to which probabilities of each event approximate $1/n$ for n possible events.

- *Conflicting* information: strong activation both for and against a hypothesis, in which the sum of + and - activation is greater than one.

In addition, by adding the temporal dimension, we get a fifth pattern:

- *Dependence on assumption*: activation that is subject to change as more information is considered (implicit assumption), or as different choices are made (explicit assumption).

Attending to a belief reflectively results in recognition of uncertainty patterns pertaining to that belief. In addition, the decision maker may employ more proactive strategies for uncovering uncertainty. Such strategies involve clamping truth values in order to consider hypothetical situations and plans, i.e., *what if* reasoning. These hypothetical beliefs and actions may activate relevant information that could not otherwise be considered. This information in turn may lead to recognition of additional gaps, conflicts, and/or assumptions.

The three major types of uncertainty (incompleteness, conflict, and assumptions) all appear in the Sanna's Post example.

Incompleteness

In Figure 2, movement of armored vehicles on the road has been predicted. Nevertheless, this node may represent a gap, since its strength of activation may be quite weak until the movement has actually been observed. Other gaps are represented by other components of the *intent* mental model that have not participated in the arguments for or against enemy intent. In particular, although enemy capability relative to friendly forces has received some activation, no specific information has been retrieved. Such information could have important consequences. For example, if the enemy expected us to be stronger in this sector, they might choose to reinforce the battalion fight by some other route.

A more proactive method for uncovering gaps is to shift attention from evidence (the presence of trucks) to conclusions (e.g., the enemy intends to use Sanna's Post as a logistics base), and clamp the conclusion true – that is, ask, *what if the conclusion is true*? This query results in the reflexive propagation of activation that is equivalent to two questions:

- How can the conclusion be explained? The attention shift may draw attention to additional gaps in the mental model representing causes of the intent. For example, the commander has considered the element of opportunity as it affects the enemy (e.g., the road), but not very thoroughly. He has not thought about other possible routes the enemy might use, and whether they offer any advantages, e.g., are they less vulnerable to ambush?
- What does the conclusion predict? The attention shift may help generate new predictions regarding expected enemy actions that can be used to test the assessment of intent.

Conflict

In Figure 3, conflicting arguments are activated about whether or not Sanna's Post is vulnerable to an attack. On the one hand, logistics bases are likely to be weakly defended. On the other hand, enemy armor is present at Sanna's Post.

Strategies for filling gaps can always lead to conflict, and so they double as strategies for finding conflict. More specific and more proactive strategies for discovering conflict are also available. To discover potential conflicting evidence, the commander can clamp *the current conclusion as false*, or *the current plan as failing to achieve its objectives.* For example, to find out if there is any evidence for an alternative explanation of the trucks at Sanna's Post, the commander can imagine that he knows that the enemy's intent is *not* to use Sanna's Post as a logistics base. This attention shift is equivalent to asking two questions of the reflexive system:

- How or why is the conclusion could be false? This may activate knowledge of alternative possible explanations for the trucks. For example, the enemy might wish to deceive us in order to fix the company and prevent us from joining the battalion fight ourselves.
- What does the falsity of the conclusion predict? The alternative explanation may lead to other predictions (e.g., regarding overall enemy strength and recent losses), which may be verified by further information collection.

Assumptions

We have already seen that a particularly important kind of assumption concerns beliefs at the edge of the currently active network: Does the historically aggregated information actually fit the current situation, or will conclusions change as more specific information about the present situation is considered? Figure 2 includes four different assumptions: regarding the prior probabilities of enemy purpose and opportunity, the expected utility of the enemy's moving reinforcements along the road through Sanna's Post, and the feasibility of destroying the enemy in Sanna's Post. In each of these cases, it is possible that past experience was non-representative, or, conversely, that the present situation is unusual.

A simple way to discover assumptions begins by recognizing the heightened *possibility* of dependence on assumptions for beliefs at the edge of the current reasoning process. These are beliefs which have simply been accepted as true, and are not embedded in a web of reasoning or observation. The decision maker can shift attention to such nodes, and determine whether the degree of belief in the event represented by the node changes as a result of newly activated information. Such newly activated information may represent plausible causes of the event, or testable predictions implied by the event.

A context in which assumptions are especially important is in the effort to resolve conflict. Since a proposition and its contradiction cannot both be true, conflict itself is a strong cue that assumptions somewhere in the system of belief are false (Cohen, 1986). The stronger the

conflict, the more likely it is that one or more of the beliefs responsible for the conflict must depend on assumptions that are false in the present situation. Such assumptions may be uncovered by shifting attention to beliefs which contribute to the conflict.

A more proactive strategy for ferreting out hidden assumptions is similar to the strategy for finding conflict. This involves clamping a conclusion as false and the evidence for the conclusion as true. In response, the system reflexively searches for alternative explanations of the evidence. If these alternatives turn out to represent gaps, i.e., there is little evidence for or against them, then the original conclusion depended on the implicit *assumption* that these alternative explanations were false.

The metacognitive system increases its effectiveness by learning strategies that are specifically tailored to each type of uncertainty.

The metacognitive system learns to combine a set of simple operations: inhibiting recognitional responding, activation of new information internally by shifting focal attention, and clamping truth values. These operations are simple and both psychologically and biologically plausible. The metacognitive system *learns* to combine these operations in response to different patterns of uncertainty by reinforcement and associative learning processes. Through such learning, the metacognitive system acquires a rich repertoire of uncertainty handling strategies based both on knowledge acquired about the specific domain, and on more generalizable principles.

Strategies utilized by the metacognitive system contain both domain-specific and general-purpose elements, to varying degrees as a function of experience. After extensive experience in a domain, decision makers learn which concepts are likely to be the major determinants of different kinds of uncertainty for other concepts. In other words, they learn to identify likely *culprits*, i.e., nodes in the active network that are likely to be responsible for the gap, conflict, or unreliable assumption that has been identified. This might include, for example, knowledge of what the typical gaps in understanding are likely to be in estimating enemy intent, what the likely causes of conflicting conclusions about enemy intent are, and where the hidden assumptions lie. These learned associations guide reflective processing. They bring with them both an increase in efficiency and the risk that novel sources of uncertainty will be overlooked

In filling gaps and in resolving conflict, the metacognitive system utilizes measures of culpability that reflect the sensitivity of belief in one node (e.g., the node where there is a gap or conflict) to changes of belief in other nodes. These are closely related to the parameters that are used to tune weights in the reflexive system to environmental correlations. The result is mastery of domain-specific strategies for metacognitive critiquing and attention-shifting.

More general strategies for reflective reasoning may also be learned, by abstracting from experience or by explicit instruction. These general strategies identify likely causes and cures for different types of uncertainty by using argument relationships. For example, decision makers

may learn than when a conflict in beliefs is discovered, they should shift attention to *evidence* for the conflicting *conclusions.*

Our discussion of Figure 2 illustrates a more general strategy. The reflective system recognized that the decision to destroy the enemy at Sanna's Post might well depend on assumptions, since the chain of reasoning that led to that response had not been thought through very deeply. As a result of this uncertainty and the high stakes of the decision, the reflective system inhibited the initial recognitional response. Instead of acting reflexively on that response, the reflective system identified it as the conclusion and shifted attention to it in order to evaluate the assumptions upon which it depended, The aim was to explore the chain of reasoning more deeply and expose information beyond the edge of the currently active network. Exposure of this information resulted in the discovery in Figure 3 of a conflict between evidence that Sanna's Post will be vulnerable to attack and evidence that it will not.

The grounds of both the optimistic and the pessimistic argument are at the edge of the current network, and thus likely to be dependent on implicit assumptions about the representativeness of historically aggregated information. To resolve the conflict, in Figure 4 the commander shifts attention to the conclusion of one of the two competing arguments (i.e., that we are outgunned by tanks at Sanna's Post). The purpose of this attention shift is to activate assumptions that may turn out not to fit this situation, that is, to expose incorrect generalizations about the strength of this defense. Activation of new information, if it results in revision of assumptions, may eliminate the conflict. If this fails, the decision maker might shift attention to the conclusion of the other competing argument.

Metacognition helps guide the dynamic retrieval and collection of new information, and facilitates learning. It thus helps *create, maintain, and improve the belief network.*

Value tradeoffs contribute to the control of reflective processing. Recognition-based and reflective responding fall along a spectrum that varies the number of attentional cycles enlisted to arrive at a conclusion or response. Decisions about whether to reflect more (i.e., engage in additional attentional cycles) or act at once on the current best response are determined by the current uncertainty of recognitional conclusions, the costs of delay, and the potential costs of errors.

CONCEPTS FOR UNCERTAINTY VISUALIZATION

A graphical user interface for the Reflexive-Reflective System has been implemented with the following features: The GUI provides a graphical display of the inferential relationships in the *network* of beliefs and actions that represents the situation. The GUI dynamically displays the current uncertainty status of each active node in working memory, in terms of *qualitatively different types of uncertainty.* The GUI supports *domain-specific* critical thinking strategies in real time, by providing information about the degree of historical *culpability* of each node in the network for uncertainty at other nodes. The GUI supports *general-purpose* critical thinking

strategies in real time, by providing information about the generic roles that nodes are currently playing within *arguments* that bear on crucial uncertainties in the current situation.

SUMMARY

In sum, there are inherent, and dynamic, limits on the scope of LTM information that can be brought to bear in interpreting any evidence. The key interaction between the reflexive and reflective systems is the adaptive direction of focused attention within the reflexive memory by means of learned metacognitive behaviors. Recency effects are used to assemble such intermediate results into composite assessments. The model suggests that the development of executive attention functions (metacognitive strategies) may be necessary for, and integral to, the development of working memory, or dynamic access to LTM. A simulation tool with these properties may be able to provide the kind of dynamic and flexible feedback and guidance that is necessary in training critical thinking skill.

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RESULTS OF GROUP DISCUSSIONS IN CRITICAL THINKING

This section summarizes the results of major themes addressed in the discussion groups and ends with recommendations for future research. The material is divided into three subsections:

- Critical thinking in battle command
- Training critical thinking in the army
- Critical research and development issues in training critical thinking.

CRITICAL THINKING IN BATTLE COMMAND

Use of Critical Thinking in Battle Command

Battle Command situations are very complex with high stakes—e.g., people's lives. They are deliberately deceptive in nature with the hostilities of the enemy at the forefront of our deliberations. We have to work in a hierarchy. We have to deal with international public perceptions. It's done in a political atmosphere with different agendas of different groups. There's a spectrum of operations from peace keeping to combat. There will be operations we cannot now imagine, let alone prepare for. Rapid advances in technology make decisions more complex.

We can't solve these complex problems without critical thinking. We especially need critical thinking to deal with novel situations. We cannot train for novel situations because we do not know what those situations will be. Even with simulations we can't simulate all possible situations. So we must train to deal with novel situations using critical thinking skills (critical thinking skills).

Battle Command tasks that particularly relate to critical thinking are:

- Visualizing operations
- Describing outcomes and projecting them
- Directing the operation with subordinates,
- Knowing when to stop and to start planning
- Assessing evidence
- Questioning assumptions
- Envisioning in time
- Keeping your eye on the goal
- Knowing when to start and stop critical thinking

Relationship between The Military Decision Making Process (MDMP) and Critical Thinking

Participants agreed that the MDMP and critical thinking are different but fit together. Critical thinking is one of the means by which the MDMP can be executed and using critical thinking can improve the quality of the products of the MDMP. Following are some of the comments on this topic.

There is no conflict between MDMP and critical thinking because they are different and they compliment each other. The MDMP could be seen as a meta-language to communicate the results of the thinking process. The MDMP is a process while critical thinking is a modifier to the process. This means you need to know the process before you can use critical thinking.

Critical thinking is used in executing the process and should be integrated into the MDMP. We need to figure out how to apply critical thinking to MDMP. The Army uses visualization, maps and mental simulation. When critical thinking is taught, it must be mapped into these procedures and in fact mapped into the whole MDMP.

Our planning assumptions have values that appear to be precise, but they are not. This is another place where we need to apply critical thinking. We can also use critical thinking to adjust the MDMP to time available, i.e. to modify the MDMP.

Incidentally, the MDMP reflects another training problem. We teach officers that the first step is an analysis of your mission and that you break the mission into its components, specified and implied tasks. Then you assign them into the stovepipe planning cells. They are kept safely in the pipeline and the only person responsible for any synthesis in the process is the commander. So one of the problems is that there is a group responsible for breaking things into small parts and only one person responsible for synthesis.

The Relationship Between Critical Thinking and Intuition

This topic generated disagreement, with some participants arguing that intuition is the result of critical thinking and therefore is analytical, and others arguing that it may or may not be the result of critical thinking, but is not analytical. Following are selected arguments made by discussants:

- I would argue that intuition is a result of critical thinking. You go through multitudes of critical thought processes about an issue and these are then stored in memory. Then you use some kind of analogical process to retrieve that information. It comes to our mind as something we call intuition and in fact it is analytic, very rational, and the product of processes that have taken place at a previous time.

- What often happens is the first thing that comes to conscious awareness is the solution. Intuition is an extremely appropriate tool of reasoning because critical thinking is linear, conscious, and requires a lot of energy. The unconscious rapid

processing can happen in parallel, takes into account a whole lot of variables based on experience, and comes up with the solution.

- Well, I disagree. It's non-analytic. Recognition prime decision-making at its simplest level is really non-analytic. It's rational, but that doesn't mean it's analytic.

- I agree with that. Intuition may be the product of critical thinking. In fact, we talked about intuition as an important element in planning. That is, applying critical thinking to planning, such that when you get to the actual execution, and you're in the throes of events, you will have worked through those ideas before. You will have foreseen the issues that might come out, because you've spent so much time planning. So that when a situation occurs, you recognize the solution and all the elements. And then when the execution is there for you, you know what it involves. The process by which you recognize and execute is not an analytic process. But it may depend on all the critical thinking you did previously. .

- I will say that the truth is on both sides here, it's non-analytic in the sense of intuition not being a serial conscious process, but there are incredible inferential powers that are unconscious. If you see Tom give Mary a book and somebody asks you who has the book: it's Mary. All this information is compiled in parallel and converges on a rapid intuitive answer. It can probably combine tens of thousands of bits of information in parallel. But it is highly inferential in the sense that you can only model it using logic or something like that. But it's certainly not a conscious thought process.

- The phenomenon of intuition on a battlefield, they describe, has been discussed in military theory. They first called it "In my mind's eye." Germans call it "Finger tip feel." Americans call it: "Good eye for battlefield." Coming back to Burt's opening comments: Pattern recognition may be a part of this. If you have a visual feel for what should be happening and if it isn't happening you can cause it to happen by influencing *something*. If on the other hand, if something's happening that you know shouldn't happen, you could do something about it. This is intuition. I would argue that this intuition is based on experiences. You can teach it - you can teach people how to have a better feel for the battlefield by putting them through dealing with experiences. I would also argue, and this is a very anti-American view, maybe there's some talent involved and some people are never going to have an eye for the battlefield.

- Intuition could be a result of critical thinking. Having gone through multitudes of critical thinking processes that get stored away, analogous thinking brings conclusions forward automatically. Recognition Primed Decision Making (RPDM) is intuition according to Gary Klein. It is rational but not analytical. Information is encoded for intuitive rapid processing. RPDM is a parallel process to critical thinking. It's not critical thinking, but we run these two on a continuing basis when we're trying to make decisions. RPDM is an important process. Military commanders use it a lot, especially experienced ones.

- We need to take leaders and decision makers, put them in increasingly complex and varied scenarios, have them make decisions, and give them feedback on their decision. And that's all rational and analytic. But as we develop true decision makers there's some automaticity there. If you create situations either through simulation or analogy, and you continually put people through them and question them and make them do critical thinking, I think you build intuition. So the pattern recognition, the intuition, starts to grow and is based on critical thinking.

BARRIERS TO CRITICAL THINKING

Following are factors the group thought were especially detrimental to conducting critical thinking.

Mental Effort

Fatigue and excessive mental workload can stop critical thinking from occurring. critical thinking is hard work and can be an unpleasant state to be in.

Critical thinking is an arduous procedure on two levels. First, there is the mental work that is done at the individual and team levels. Second, the prospect of having to change decisions and judgments as a result of critical thinking can discourage critical thinking. Knowing how to manage one's cognitive resources to meet the demands of the task is an important part of being able to think critically.

Social awkwardness can discourage critical thinking

If one is concerned about the social acceptance of people who's work you are critiquing, this may discourage critical thinking. Social skills are important when using critical thinking skills in social and team settings. We need to teach social skills when using critical thinking so we don't alienate people. But if we make routine the use of critical thinking, then critical thinking becomes part of the process and is expected. Then people will then not feel attacked if their work is critiqued.

Army Cultural Climate

The command climate can either nurture or stifle critical thinking. We need to create a culture in which officers can think critically. But this is not only a problem for the Army; it's a problem for most large organizations. critical thinking is impossible to achieve unless the culture supports it. We like to think rational argument will carry the day. But the political and cultural climates are too important. The organizational culture can be an impediment to creating an environment in which it's possible to think critically. The hierarchical authority structure discourages a younger officer with coming up with a novel idea that may be at odds with his commanding officer's ideas.

Lack of Time

Critical thinking requires a certain amount of time to execute. It's not instantaneous. If there is not enough time, critical thinking may default to intuition.

TRAINING CRITICAL THINKING SKILLS IN THE ARMY

How do we currently develop/ train critical thinking in Army Officers?

Current critical thinking training in officers uses the three pillars of the professional development model – institutional training, self-development and operational assignments.

Institutional Training

Here we have small groups, seminars, trained instructors, retired officer training facilitators, and simulations. The experiential learning model is used. One problem here is that junior people are given course design responsibility before they are expert in applying critical thinking skills to planning.

Operational Assignments

It is easier to teach critical thinking in the field because we have more freedom. After Action Reviews (AARs) including Observer Controllers is a successful model. The emphasis here is on finding out how to get better vs. finding the right answer. Increasing experience opportunities can be used to shorten the learning cycle.

Self Development

While professional development is a great mechanism, there isn't much in there that talks about critical thinking. If we want to get people to think more about critical thinking we need to make sure it's in the reading lists that we give to people. On the other hand, you don't learn to apply critical thinking by studying critical thinking in theory and principle. You learn by doing it. If we really want to make critical thinking a natural way of thinking we need to show them how they can apply critical thinking in all kinds of contexts – at home, in their physical fitness, as well as in their professional lives.

Where does distance learning fit? In terms of self-development, we are moving into this education mode using computers, email and web sites. But how does it all fit together? Do we give people enough time to take advantage of these? We need to make sure people have the resources they need to do self-development. Perhaps we can use reading lists and encourage books about critical thinking. And how do we reward people for doing that. Right now the reward system does not support those who do self-development.

WHAT WORKS WELL IN HOW WE CURRENTLY TRAIN CRITICAL THINKING IN THE ARMY?

After Action Reviews

This can be a very effective way to teach critical thinking. The Observer controllers give feedback based on their experience and formal training in observation, questioning and interaction skills. The Observer controllers should think about how they're going to get critical thinking feedback to the soldiers, and what looks right.

Performance Based Training

Anything that's performance based and uses coaching can be effectively used for teaching critical thinking. In the School for Command Preparation students actually go through a series of activities and critical thinking could be used in these exercises and modeled by the instructors. The Common Mission Rehearsal Exercises at the CMTC are also very effective ways to train critical thinking skills.

Think Like a Commander

The Think Like a Commander (TLAC) vignette program, is a new training program to train adaptive leaders from the brigade commander down. The Initial Brigade Combat Team at Ft. Lewis has a program similar to TLAC. An idea in TLAC is to get subordinates to think like their commanders, to think at a higher level. TLAC takes a vignette to the next level and creates a simulation where it presents a situation to a commander in the context of a problem that they're already been given. But now, the situation is something different than they've had to consider. He is then asked to think like a commander, not to make decisions but to think like a commander. He works through his interpretation of the problem, his reasoning and the types of actions he might take. Then we relate back how they thought about it to how great commanders look at a problem. They start to see similarities. After 4 or 5 vignettes they start to develop a pattern of though and to consider areas they may not have considered in earlier vignettes. They think a little richer and deeper about the process. TLAC focuses on critical thinking. This could be used as a paradigm for training critical thinking.

MAKING THE FISCHER CRITICAL THINKING MODEL MORE RELEVANT TO BATTLE COMMAND

There was a great deal of disagreement about whether to show students the Fischer model and train them using the model. Proponents thought showing students the model would give them the big picture of the factors affecting critical thinking while opponents thought use of the model would focus students on the theories underlying critical thinking rather than executing the skills themselves.

Other representative comments included:

- The model is too static to represent the dynamic thinking that goes on in visualization. It needs to be enhanced by bringing time and dynamicity into those skills. It needs a goal orientation to better represent the military dynamics present in the planning process.

- The model should address how to select the appropriate cognitive skill relative to the requirements of the problem.

- Intuition is not included in the model. Officers have an innate sense of what is right and wrong based on experience. When a battalion commander has 20-25 years of experience, you ought to be able to depend on him to make intuitive decisions that are correct. Other discussion participants disagreed with this comment. They felt that if you're falling into intuitive decisions you are not considering other alternatives. You are not thinking critically.

- The use of maps is a necessary part of the MDMP. Visual representations are tools to aid critical thinking dialog and tools to communicate. How can we support critical thinking mental simulations using dynamic maps? How can we blend visualization and critical thinkingS in the model? Visualization and mental simulation are equivalent in Army planning.

RECOMMENDATIONS FOR IMPROVING CRITICAL THINKING TRAINING IN THE ARMY

Capitalize on what works well now.

Routinely incorporate feedback on critical thinking in the formal AARs. The AARs should also include feedback on team dynamics in critical thinking and interpersonal skills using critical thinking in teams. Use performance-based training with coaching. The TLAC program might be used as a model for how to train critical thinking skills.

Design digital capabilities to aid and facilitate critical thinking.

Training critical thinking should be in the context of the Army digital technology.

Now that we use digital tools in decision making, we need to also re-look our decision-making processes. With technology we start assigning objective values to things that should be evaluated subjectively. When these objective values are put in a computer, and it comes up with an answer, we think it must be right. The values we deal with have apparent objective values and an apparent precision they may not have. So we need to be critical and evaluate whether the technological process is appropriate for the problem. The Army needs to be critical about the products of technology and the information products of technology. Too often we are too accepting of the products of technology. This is a place for critical thinking – in evaluating the products of technology. We need to be able to think critically about technology.

Make it easy for the instructors to train critical thinking.

In the Leader Instructor Division (LID) of CGSC, they came up with ten great generic questions which could be embedded in the lesson plans, e.g. questioning assumptions. The Instructors can then modify these base questions. They can be used in the AARs. Develop similar generic questions Instructors can use for training critical thinking.

Train critical thinking using time pressure.

If you train critical thinking with no time pressure, then attempt critical thinking under pressure, it may break down. People skip over steps under time pressure and there may be a default to intuition. Under time pressure there is less time to think through something systematically. Under stress you may have other cognitive tasks that drain the cognitive resources so one can't do thorough cognitive processes. Problem solving may deteriorate under high stress. But if critical thinking is practiced under stress and time stress, officers are better prepared to do critical thinking under these conditions.

Give guidance on when to use and when not to use critical thinking.

Teach rapid recognition/intuition vs. critical thinking. We train to critically think when we have the time to think. But knowing when not to use critical thinking and to use intuition instead may be just as important as when to use critical thinking.

Don't offer answers.

In training critical thinking, continue to focus on the question because as soon as you allow or accept an answer, you immediately stop all thinking about that particular topic, and you're ready to move on to the next. Just keep asking the questions and go deeper and deeper.

Explicitly train the process of critical thinking.

The development of critical thinking skills can be accelerated by making the process explicit. Take advantage of the science of learning. critical thinking skills training should be planned and deliberately inserted in courses, and not left to chance. However, it should also be incorporated in all courses by having instructors model how critical thinking applied to the MDMP and reinforce and require the use of critical thinking in their students.

Train a variety of critical thinking skills.

Train the ability to select an appropriate skill for the situation. If people have a toolbox of critical thinking skills, they will be better able to meet the unfamiliar challenges they will face in the future.

Train interpersonal skills for the application of critical thinking.

One of the barriers to the use of critical thinking is social awkwardness. Even though one has critical thinking skills, if one is not able to use them in group settings without alienating

group members, those skills won't be used. Use of them will be punished by the other group members.

Train attitudes.

Attitudes about critical thinking are important in determining whether people will use critical thinking and these attitudes can be trained. Persistence, open mindedness and a willingness to expend effort are necessary in using critical thinking.

Train for transfer of training.

Even using simulations, we can't simulate all possible situations. So training to deal with novel situations using critical thinking skills should be planned for and part of the course design. Methods for facilitating transfer of training to other situations are available and can be used when designing critical thinking training.

Instructors should model use of critical thinking skills.

Training should also show students what critical thinking looks like, either by showing them someone who is critically thinking or by showing them a way to walk through the problem using a set of principles. This means that the Instructors must be good critical thinkers themselves and receive training and feedback themselves in critical thinking.

Include critical thinking training in every course that's taught in the Army.

This could be done without additional resources. This is currently promoted/done in universities. You can take any course (history, math) you're teaching and include elements that promote critical thinking. Here's how you do it. This is just what Dr. Halpern talked about yesterday. You don't ask them to memorize and regurgitate information. You ask them to think about it. And not only that, but the Instructor is an on-the-spot assessment and evaluation instrument of that critical thinking. Instructors should not reinforce students when students just regurgitating what they have been told they need to know, but instead reinforce working through problems. Instructors can ask open-ended questions instead of multiple-choice questions.

On the other hand, another discussant thought that it's pretty easy to include the principles and standards of critical reasoning and creative thinking in task standards and when developing learning standards. It takes 5 minutes. But to get someone to facilitate his classroom in accordance with those principles takes an awful lot of resources. It takes training, time, dedication, someone to evaluate what the Instructor is doing. If you've got 200 instructors, it's very difficult to infuse them with the desire to embed critical thinking principles throughout their instruction. It sounds pretty easy, but it's very difficult to accomplish. Not impossible, and well worth the effort.

Foster an Army culture that values critical thinking.

If the Army fails to encourage and reward creative and critical thinking within its officer and NCO corps, further research and training efforts in the area of critical thinking will be wasted efforts. An organizational culture with norms that punish critical thinking or the behaviors needed to develop critical thinking skills can have a chilling effect on the development of critical thinking within the organization—no matter how much lip service is paid to the concept of critical thinking by organizational leadership. For example, courses on critical thinking can be incorporated into the Army's institutional training curricula and can be incorporated into training doctrine. However, as long as there exist leadership positions within the Army that do not allow their subordinates the discretion to use these skills, these skills and the incentive to use them will deteriorate.

CRITICAL RESEARCH AND DEVELOPMENT ISSUES

Following are major research and development issues that workshop participants thought must addressed if Army critical thinking training was to be effective.

Development of valid evaluation methods and measures of critical thinking

Evaluation is critically important because we can't effectively train critical thinking if we don't know if the training is working. We need a more explicit approach to evaluation. Historically, measurement of critical thinking has been problematic. However, without valid evaluations, we can't know if the training is effective, what parts are working, what needs to be changed, and how good the instructors are. We also need data on critical thinking measures of performance and effectiveness to show that critical thinking training is worth the Army's investment of time and money and to convince instructors to buy into the critical thinking concept.

Measurement of critical thinking is also important if the Army culture is to reward critical thinking. 360 degree assessments do not have much to do with critical thinking. How do you measure critical thinking for OER?

Team training of critical thinking

This is a research area that has not received much attention. However, since most of the Army's planning and execution is done in the context of teams, we need to know how individual critical thinking affects team performance and how the team context affects individual critical thinking. How can critical thinking be effectively implemented in team environments? How can we train critical thinking for effective team performance? What kind of interpersonal skills are needed to implement critical thinking in teams?

Individual differences in critical thinking. What conditions elicit critical thinking? What conditions stop critical thinking?

An area of research that has received less attention is identifying the individual difference variables that may lead to critical thinking. For example, Fischer's paper suggests some predisposing attitudes that may lead to a propensity to engage in critical thinking, such as skepticism, curiosity, persistence and resistance to anxiety. Additionally, both Fischer's and Halpern's papers discuss the cognitive antecedents to cr al thinking. However, the nomological network of such antecedents to critical thi g should be broadened to include other important individual differences, such as individual's valuation of critical thinking and their motivation to engage in critical thinking. For example, given that the critical thinking state is largely considered to be unpleasant, research should investigate the individual differences that predispose individuals to engage in a critical thinking state. Similarly, research could also be directed at identifying individual differences and motivational forces that relate to maintaining and exiting the critical thinking state, as well as those that impact the effectiveness of one's critical thinking "output." Only with more research into these areas can researchers begin to develop predictors of individual's propensity toward critical thinking that can be used to identify critical thinkers and to identify those who would most benefit from critical thinking training.

Simulations to explore "what if" thinking and provide intelligent feedback

We should invest in research and development for sophisticated simulations. Simulations can create complex situations and provide experiences that would not be possible otherwise. In acquiring critical thinking skills, practice and experience is critical. These skills can't be learned through lectures or books. Feedback is also critical to learning. Distance learning and self-development software with critical thinking will never be effective without advanced feedback capabilities.